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VOLUME V.

PHILOSOPHY: ITS FUNDAMENTAL CONCEPTIONS AND ITS METHODS.

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THE duty has been assigned me, honored colleagues, of addressing you on the Fundamental Conceptions and the Methods of our common pursuit—philosophy. In endeavoring to deal with the subject in a way not unworthy of its depth and its extent, I have found it impossible to bring the essential material within less compass than would occupy, in reading, at least four times the period granted by our programme. I have therefore complied with the rule of the Congress which directs that, if a more extended writing be left with the authorities for publication, the reading must be restricted to such a portion of it as will not exceed the allotted time. I will accordingly read to you, first, a brief summary of my entire discussion, by way of introduction, and then an excerpt from the larger document, which may

serve for a *specimen,* as our scholastic predecessors used to say, of the whole inquiry I have carried out. The impression will, of course, be fragmentary, and I must ask beforehand for your most benevolent allowances, to prevent a judgment too unfavorable.

The discussion naturally falls into two main parts: the first dealing with the Fundamental Conceptions; and the second, with the Methods.

In the former, after presenting the conception of philosophy itself, as *the consideration of things in the light of the whole,* I take up the involved Fundamental Concepts in the following order:—

I. Whole and Part;
II. Subject and Object (Knowing and Being, Mind and Matter; Dualism, Materialism, Idealism);
III. Reality and Appearance (Noumenon and Phenomenon);
IV. Cause and Effect (Ground and Consequence; Causal System);
V. One and Many (Number System; Monism and Pluralism);
VI. Time and Space (their relation to Number; their Origin and Real Meaning);
VII. Unconditioned and Conditioned (Soul World, God; their Reinterpretation in terms of Pluralism);
VIII. The True, the Beautiful, the Good (their relation to the question between Monism and Pluralism).

These are successively dealt with as they rise one out of the other in the process of interpreting them and applying them in the actual creation of philosophy, as this goes on in the historic schools. The theoretic progress of philosophy is in this way explained by them, in its movement from natural dualism, or realism, through the successive forms

of monism, materialistic, agnostic, and idealistic, until it reaches the issue, now coming so strongly forward within the school of idealism, between the adherents of monism and those of pluralism.

The importance of the Fundamental Concepts is shown to increase as we pass along the list, till on reaching Cause and Effect, and entering upon its full interpretation into the complete System of Causes, we arrive at the very significant conception of the Reciprocity of First Causes, and through it come to the Primacy of Final Cause, and the derivative position of the other forms of cause, Material, Formal, Efficient. The philosophic strength of idealism, but especially of idealistic pluralism, comes into clear light as the result of this stage of the inquiry. But it appears yet more decidedly when One and Many, Time and Space, and their interrelations, are subject to analysis. So the discussion next passes to the higher conceptions. Soul, World, God, by the pathway of the correlation Unconditioned and Conditioned, and its kindred contrasts Absolute and Relative, Necessary and Contingent, Infinite and Finite, corroborating and reinforcing the import of idealism, and, still more decidedly, that of its plural form. Finally, the strong and favorable bearing of this last on the dissolution of agnosticism and the habilitation of the ideals, the True, the Beautiful, and the Good, in a heightened meaning, is brought out.

This carries the inquiry to the second part of it, that of the Philosophical Methods. Here I recount these in a series of six: the Dogmatic, the Skeptical, the Critical, the Pragmatic, the Genetic, the Dialectic. These, I show, in spite of the tendency of the earlier members in the series to over-emphasis, all have their place and function in the development of a complete philosophy, and in fact form an ascending series in methodic effectiveness, all that precede

the last being taken up into the comprehensive Critical Rationalism of the last. Methodology thus passes upward, over the ascending and widening roadways of (1) Intuition and Deduction; (2) Experience and Induction; (3) Intuition and Experience adjusted by Critical Limits; (4) Skepticism reinforced and made *quasi*-affirmative by Desire and Will; (5) Empiricism enlarged by substitution of cosmic and psychic history for subjective consciousness; (6) Enlightened return to a Rationalism critically established by the inclusion of the preceding elements, and by the sifting and the grading of the Fundamental Concepts through their behavior when tested by the effort to make them universal. In this way, the methods fall into a System, the organic principle of which is this principle of Dialectic, which proves itself alone able to establish *necessary* truths; that is, *truths indeed*,—judgments that are seen to exclude their opposites, because, in the attempt to substitute the opposite, the place of it is still filled by the judgment which it aims to dislodge.

And now, with your favoring leave, I will read the excerpt from my larger text.

The task to which, in an especial sense, the cultivators of philosophy are summoned by the plans of the present Congress of Arts and Science, is certainly such as to stir an ambition to achieve it. At the same time, it tempers eagerness by its vast difficulty, and the apprehension lest this may prove insuperable. The task, the officers of the Congress tell us, is no less than to promote the unification of all human knowledge. It requires, then, the reduction of the enormous detail in our present miscellany of sciences and arts, which to a general glance, or even to a more intimate view, presents a confusion of differences that seems overwhelming, to a system nevertheless clearly harmonious, —founded, that is to say, upon universal principles which

control all differences by explaining them, and which therefore, in the last resort, themselves flow lucidly from a single supreme principle. Simply to state this meaning of the task set us, is enough to awaken the doubt of its practicability.

This doubt, we are bound to confess, has more and more impressed itself upon the general mind, the farther this has advanced in the experience of scientific discovery. The very increase in the multiplicity and complexity of facts and their causal groupings increases the feeling that at the root of things there is "a final inexplicability"—total reality seems, more and more, too vast, too profound, for us to grasp or to fathom. And yet, strangely enough, this increasing sense of mysterious vastness has not in the least prevented the modern mind from more and more asserting, with a steadily increasing insistence, the essential and unchangeable unity of that whole of things which to our ordinary experience, and even to all our sciences, appears such an endless and impenetrable complex of differences,—yes, of contradictions. In fact, this assertion of the unity of all things, under the favorite name of the Unity of Nature, is the pet dogma of modern science; or, rather, to speak with right accuracy, it is the stock-in-trade of a *philosophy* of science, current among many of the leaders of modern science; for every such assertion, covering, as it tacitly and unavoidably does, a view about the absolute whole, is an assertion belonging to the province of philosophy, before whose tribunal it must come for the assessment of its value. The presuppositions of all the special sciences, and, above all, this presupposition of the Unity and Uniformity of Nature, common to all of them, must thus come back for justification and requisite definition to philosophy—that uppermost and all-inclusive form of cognition which addresses itself to the whole as whole. In their common as-

sertion of the Unity of Nature, the exponents of modern science come unawares out of their own province into quite another and a higher; and in doing so they show how unawares they come, by presenting in most instances the curious spectacle of proclaiming at once their increasing belief in the unity of things, and their increasing disbelief in its penetrability by our intelligence:—

> *In's Innere der Natur,*
> *Dringt kein erschaffner Geist,*

is their chosen poet's expression of their philosophic mood. Curious we have the right to call this state of the scientific mind, because it is to critical reflection so certainly self-contradictory. How can there be a real unity belonging to what is inscrutable?—what evidence of unity can there be, except in intelligible and explanatory continuity?

But, at all events, this very mood of agnostic self-contradiction, into which the development of the sciences casts such a multitude of minds, brings them,—brings all of us,—as already indicated, into that court of philosophy where alone such issues lawfully belong, and where alone they can be adjudicated. If the unification of the sciences can be made out to be real by making out its sole sufficient condition, namely, that there is a genuine, and not a merely nominal, unity in the whole of reality itself,—a unity that explains because it is itself, not simply intelligible, but the only completely intelligible of things,—this desirable result must be the work of philosophy. However difficult the task may be, it is rightly put upon us who belong to the Department listed first among the twenty-four in the programme of this representative Congress.

I cannot but express my own satisfaction, as a member of this Department, nor fail to extend my congratulations to you who are my colleagues in it, that the Congress, in

its programme, takes openly the affirmative on this question of the possible unification of knowledge. The Congress has thus declared beforehand for the practicability of the task it sets. It has even declared for its not distant accomplishment; indeed, not impossibly, its accomplishment through the transactions of the Congress itself; and it indicates, by no uncertain signs, the leading, the determining part that philosophy must have in the achievement. In fact, the authorities of the Congress themselves suggest a solution of their own for their problem. In their programme we see a renewed Hierarchy of the Sciences, and at the summit of this appears now again, after so long a period of humiliating obscuration, the figure of Philosophy, raised anew to that supremacy, as Queen of the Sciences, which had been hers from the days of Plato to those of Copernicus, but which she began to lose when modern physical and historical research entered upon its course of sudden development, and which, until recently, she has continued more and more to lose as the sciences have advanced in their career of discoveries,—ever more unexpected, more astonishing, yet more convincing and more helpful to the welfare of mankind. May this sign of her recovered empire not fail! If we rejoice at the token, the Congress has made it our part to see that the title is vindicated. It is ours to show this normative function of philosophy, this power to reign as the unifying discipline in the entire realm of our possible knowledge; to show it by showing that the very nature of philosophy—its elemental concepts and its directing ideals, its methods taken in their systematic succession—is such as must result in a view of universal reality that will supply the principle at once giving rise to all the sciences and connecting them all into one harmonious whole.

Such, and so grave, my honored colleagues, is the duty

assigned to this hour. Sincerely can I say, Would it had fallen to stronger hands than mine! But since to mine it has been committed, I will undertake it in no disheartened spirit; rather, in that temper of animated hope in which the whole Congress has been conceived and planned. And I draw encouragement from the place, and its associations, where we are assembled—from its historic connections not only with the external expansion of our country, but with its growth in culture, and especially with its growth in the cultivation of philosophy. For your speaker, at least, can never forget that here in St. Louis, the metropolis of the region by which our national domain was in the Louisiana Purchase so enlarged,—here was the centre of a movement in philosophic study that has proved to be of national import. It is fitting that we all, here to-day, near to the scene itself, commemorate the public service done by our present National Commissioner of Education and his group of enthusiastic associates, in beginning here, in the middle years of the preceding century, those studies of Kant and his great idealistic successors that unexpectedly became the nucleus of a wider and more penetrating study of philosophy in all parts of our country. It is with quickened memories belonging to the spot where, more than five-and-thirty years ago, it was my happy fortune to take some part with Dr. Harris and his companions, that I begin the task assigned me. The undertaking seems less hopeless when I can here recall the names of the congenial labors of Harris, of Davidson, of Brockmeyer, of Snider, of Watters, of Jones, —half of them now gone from life. They "builded better than they knew;" and, humbly as they may themselves have estimated their ingenuous efforts to gain acquaintance with the greatest thoughts, history will not fail to take note of what they did, as marking one of the turning-points in the culture of our nation. The publication of the *Journal of*

Speculative Philosophy, granting all the subtractions claimed by its critics on the score of defects (of which its conductors were perhaps only too sensible), was an influence that told in all our circles of philosophical study, and thence in the whole of our social as well as our academic life.

[Here I enter upon the discussion of the subject proper beginning, as above indicated, with the Fundamental Conceptions. Having followed these through the contrasts Whole and Part, Subject and Object, Reality and Appearance (or Noumenon and Phenomenon), and developed the bearing of these on the procedure of thought from the dualism of natural realism to materialism and thence to idealism, with the issue now coming on, in this last, between monism and pluralism, I strike into the contrast Cause and Effect, and, noting its unfolding into the more comprehensive form of Ground and Consequence, go on thence as follows:]

It is plain that the contrast Ground and Consequence will enable us to state the new issue with closer precision and pertinence than Reality and Appearance, Noumenon and Phenomenon, can supply; while, at the same time, Ground and Consequence exhibits Cause and Effect as presenting a contrast that only fulfills what Noumenon and Phenomenon foretold and strove towards; in fact, what was more remotely, but not less surely, also indicated by Whole and Part, Knowing and Being, Subject and Object. For in penetrating to the coherent meaning of these conceptions, the philosophic movement, as we saw, advanced steadily to the fuller and fuller translating of each of them into the reality that unifies *by explanation,* instead of pretending to explain by merely unifying; and this, of course, will now be put forward explicitly, in the clarified category of Cause and Effect, transfigured from a physical into a purely logical re-

lation. What idealism now says, in terms of this, is that the Cause (or, as we now read it, the Ground) of all that exists is the Subject; is Mind, the intelligently Self-conscious; and that all things else, the *mere* objects, material things, are its Consequence, its Outcome,—in that sense its Effect. And what the new pluralistic idealism says, is that the *assemblage of individual minds*—intelligence being essentially personal and individual, and never merely universal and collective—is the true total Cause of all, and that every mind thus belongs to the order of First Cause; nevertheless, that part, and the most significant part; of the nature of every mind, essential to its personality and its reason, is *its recognition of other minds in the very act of its own self-definition.* That is to say, a mind by its spontaneous nature as intelligence, by its intrinsic rational or logical genius, puts itself as member of a *system* of minds; all minds are put by each other as Ends—completely standard and sacred Objects, as much parts of the system of true Causes as each is, in its capacity of Subject; and we have a noumenal Reality that is properly to be described as the eternal Federal Republic of Spirits.

Consequently, the relation of Cause and Effect now expands and heightens into a system of the RECIPROCITY OF FIRST CAUSES; causes, that is, which, while all coefficients in the existence and explanation of that natural world of experience which forms their passive effect, their objects of mere perception, are themselves related only in the higher way of Final Causes—that is, Defining-Bases and Ends—of each other, making them the logical Complements, and the Objects of conduct, all for each, and each for all. Hence, the system of causation undergoes a signal transformation, and proves to be organized by Final Cause as its basis and root, instead of by Efficient Cause, or Originating Ground, as the earlier stages of thinking had always assumed.

The causal relation between the absolute or primary realities being purely Final, or Defining and Purposive; that is to say, the uncoercive influence of recognition and ideality; all the other forms of cause, as grouped by Aristotle,—Material, Formal, and Efficient,—are seen to be the derivatives of Final Cause, as being supplied by the action of the minds that, as absolute or underived realities, exist only in the relation of mutual Complements and Ends. Accordingly, Efficient Cause operates only from minds, as noumena, to matter, as their phenomenon, their presented contents of experience; or, in a secondary and derivative sense, from one phenomenon to another, or from one group of phenomena to another group, these playing the part of transmitters, or (as some logicians would say) Instrumental Causes, or Means. Cause, as Material, is hence defined as the elementary phenomenon, and the combinations of this; and therefore, strictly taken, is merely Effect (or Outcome) of the self-active consciousness, whose spontaneous forms of conception and perception become the Formal Cause that organizes the sum of phenomena into cosmic harmony or unity.

Here, accordingly, comes into view the further and in some respects deeper conceptual pair, Many and One. The history of philosophic thought proves that this antithesis is darkly obscure and deeply ambiguous; for about it have centred a large part of the conflicts of doctrine. This pair has already been used, implicitly, in exhibiting the development of the preceding group, Cause and Effect; and in so using it we have supplied ourselves with a partial clarification of it, and with one possible solution of its ambiguity. We have seen, namely, how our strong natural persuasion that philosophy guided by the fundamental concept Cause must become the search for the One amid the wilderness of the Many, and that this search cannot be satisfied and ended

except in an all-inclusive Unit, in which the Many is embraced as the integral and originated parts, completely determined, subjected, and controlled, may give way to another and less oppressive conception of unity; a conception of it as the harmony among many free and independent primary realities, a harmony founded on their intelligent and reasonable mutual recognition. This conception casts at least *some* clearing light upon the long and dreary disputes over the Many and the One; for it exposes, plainly, the main source of them. They have arisen out of two chief ambiguities,—the ambiguity of the concept One, and the ambiguity of the concept Cause in its supreme meaning. The normal contrast between the One and the Many is a clear and simple contrast: the One is the single unit, and the Many is the repetition of the unit, or is the collection of the several units. But if we go on to suppose that there is a collection or sum of all possible units, and call this the Whole, then, since there can be no second such, we call it also "one" (or the One, by way of preëminence), overlooking the fact that it differs from the simple one, or unit, *in genere;* that it is in fact not a unit at all, not an elementary member of a series, but the annulment of all series; that our name "one" has profoundly changed its meaning, and now stands for the Sole, the Only. Thus, by our forgetfulness of differences, we fall into deep water, and, with the confused illusions of the drowning, dream of the One and All as the single *punctum originationis* of all things, the Source and Begetter of the very units of which it is in reality only the resultant and the derivative. Or, from another point of view, and in another mood, we rightly enough take the One to mean the coherent, the intelligible, the consistent, the harmonious; and putting the Many, on the misleading hint of its contrast to the unit, in antithesis to this One of harmony, we fall into the belief that the Many

cannot be harmonious, is intrinsically a cluster of repulsions or of collisions, incapable of giving rise to accord; indeed, essentially hostile to it. So, as accord is the aim and the essence of our reason, we are caught in the snare of monism, pluralism having apparently become the equivalent of chaos, and thus the *bête noir* of rational metaphysics. Nay, in the opposed camp itself, some of the most ardent adherents of pluralism, the liveliest of wit, the most exuberant in literary resources, are the abjectest believers in the hopeless disjunction and capriciousness of the plural, and hold there is a rift in the texture of reality that no intelligence, "even though you dub it 'the Absolute,'" can mend or reach across. Yet surely there is nothing in the Many, as a sum of units, the least at war with the One as a system of harmony. On the contrary, even in the pure form of the Number Series, the Many is impossible except on the principle of harmony,—the units can be collected and summed (that is, constitute the Many), only if they cohere in a community of intrinsic kindred. Consequently the whole question of the chaotic or the harmonic nature of a plural world turns on the nature of the genus which we find characteristic of the absolutely (*i. e.*, the unreservedly) real, and which is to be taken as the common denomination enabling us to count them and to sum them. When minds are seen to be necessarily the primary realities, but *also necessarily federal* as well as individual, the illusion about the essential disjunction and non-coherence of the plurally real dissolves away, and a primordial world of manifold persons is seen to involve no fundamental or hopeless anarchy of individualism, irreducible in caprice, but an indwelling principle of harmony, rather, that from the springs of individual being intends the control and composure of all the disorders that mark the world of experiential appearance, and so must tend perpetually to effect this.

The other main source of our confusions over the Many and the One is the variety of meaning hidden in the concept Cause, and our propensity to take its most obvious but least significant sense for its supreme intent. Closest at hand, in experience, is our productive causation of changes in our sense-world, and hence most obvious is that reading of Cause which takes it as the producer of changes and, with a deeper comprehension of it, of the inalterable linkage between changes, whereby one follows regularly and surely upon another. Thus what we have in philosophy agreed to call Efficient Cause comes to be mistaken for the profoundest and the supreme form of cause, and all the other modes of cause, the Material (or Stuff), the Form (or Conception), and the End (or Purpose), its consequent and derivative auxiliaries. Under the influence of this strong impression, we either assume total reality to be One Whole, all-embracing and all-producing of its manifold modes, or else view it as a duality, consisting of One Creator and his manifold creatures. So it has come about that metaphysics has hitherto been chiefly a contention between pantheism and monotheism, or, as the latter should for greater accuracy be called, monarchotheism; and, it must be acknowledged, this struggle has been attended by a continued (though not continual) decline of this later dualistic theory before the steadfast front and unyielding advance of the older monism. Thus persistent has been the assumption that harmony can only be assured by the unity given in some single productive causation: the only serious uncertainty has been about the most rational way of conceiving the operation of this Sole Cause; and this doubt has thus far, on the whole, declined in favor of the Elder Oriental or monistic conception, as against the Hebraic conception of extraneous creation by fiat. The frankly confessed mystery of the latter, its open appeal to miracle,

places it at a fatal disadvantage with the Elder Orientalism, when the appeal is to reason and intelligibility. It is therefore no occasion for wonder that, especially since the rise of the scientific doctrine of Evolution, with its postulate of a universal unity, self-varying yet self-fulfilling, even the leaders of theology are more and more falling into the monistic line and swelling the ever-growing ranks of pantheism. If it be asked here, *And why not?—where is the harm of it?—is not the whole question simply of what is true?* the answer is, *The mortal harm of the destruction of personality, which lives or dies with the preservation or destruction of individual responsibility; while the completer truth is, that there are other and profounder (or, if you please, higher) truths than this of explanation by Efficient Cause.* In fact, there is a higher conception of Cause itself than this of production, or efficiency; for, of course, as we well might say, that alone can be the supreme conception of Cause which can subsist between absolute or unreserved realities, and such must exclude their production or their necessitating control by others. So that we ought long since to have realized that Final Cause, the recognized presence to each other as unconditioned realities, or Defining Auxiliaries and Ends, is the sole causal relation that can hold among primary realities; though among such it *can* hold, and in fact must.

For the absolute reality of personal intelligences, at once individual and universally recognizant of others, is called for by other conceptions fundamental to philosophy. These other fundamental concepts can no more be counted out or ignored than those we have hitherto considered; and when we take them up, we shall see how vastly more significant they are. They alone will prove supreme, truly organizing, normative; they alone can introduce gradation in truths, for they alone introduce the judgment of worth,

of valuation; they alone can give us counsels of perfection, for they alone rise from those elements in our being which deal with ideals and with veritable Ideas. So let us proceed to them.

Our path into their presence, however, is through another pair, not so plainly antithetic as those we have thus far considered. This pair that I now mean is Time and Space, which, though not obviously antinomic, yet owes its existence, as can now be shown, to that profoundest of concept-contrasts which we earlier considered under the head of Subject and Object, when the Object takes on its only adequate form of Other Subject. But in passing from the contrast One and Many towards its rational transformation into the moral society of Mind and Companion Minds, we break into this pair of Time and Space, and must make our way through it by taking in its full meaning.

Time and Space play an enormous part in all our empirical thinking, our actual use of thought in our sense-perceptive life. And no wonder; for, in coöperation, they form the postulate and condition of all our possible sensuous consciousness. Only on them as backgrounds can thought take on the peculiar clearness of an image or a picture; only on the screens which they supply can we literally *depict* an object. And this clarity of outline and boundary is so dear to our ordinary consciousness, that we are prone to say there is no sufficient, no real clearness, unless we can clarify by the bounds either of place or of date, or of both. In this mood, we are led to deny the reality and validity of thought altogether, when it cannot be defined in the metes and bounds afforded by Time or by Space: that which has no date nor place, we say,—no extent and no duration,—cannot be real; it is but a pseudo-thought, a pretense and a delusion. Here is the extremely plausible foundation of the philosophy known as sensationism, the

refined or second-thought form of materialism, in which it begins its euthanasia into idealism.

Without delaying here to criticise this, let us notice the part that Time and Space play in reference to the conceptual pair we last considered, the One and the Many; for not otherwise shall we find our way beyond them to the still more fundamental conceptions which we are now aiming to reach. Indeed, it is through our surface-apprehension of the pair One and Many, as this illumines experience, that we most naturally come at the pair Time and Space; so that these are at first taken for mere generalizations and abstractions, the purely nominal representatives of the actual distinctions between the members of the Many by our sense-perception of this from that, of here from there, of now from then. It is not till our reflective attention is fixed on the fact that *there* and *here, now* and *then,* are *peculiar* distinctions, wholly different from other contrasts of this with that,—which may be made in all sorts of ways, by difference of quality, or of quantity, or of relations quite other than place and date,—it is not till we realize this *peculiar* character of the Time-contrast and the Space-contrast, that we see these singular differential *qualia* cannot be derived from others, not even from the contrast One and Many, but are independent, are themselves underived and spontaneous utterances of our intelligent, our percipient nature. But when Kant first helped mankind to the realization of this spontaneous (or *a priori*) character of this pair of perceptive conditions, or Sense-Forms, he fell into the persuasion, and led the philosophic world into it, that though Time and Space are not derivatives of the One and the Many read as the numerical aspect of our perceptive experiences, yet there *is* between the two pairs a connection of dependence as intimate as that first supposed, but in exactly the opposite sense; namely, that the One and the Many

are conditioned by Time and Space, or, when it comes to the last resort, are at any rate completely dependent upon Time. By a series of units, this view means, we really understand a set of items discriminated and related either as points or as instants: in the last analysis, as instants: that is, it is impossible to apprehend a unit, or to count and sum units, unless the unit is taken as an instant, and the units as so many instants. Numbers, Kant holds, are no doubt pure (or quite unsensuous) percepts,—discerned particulars,—therefore spontaneous products of the mind *a priori,* but made possible only by the primary pure percept Time, or, again, through the mediation of this, by the conjoined pure percept Space; so that the numbers, in their own pure character, are simply the instants in their series. As the instants, and therefore the numbers, are pure percepts,—particulars discerned without the help of sense,—so pure percepts, in a primal and comprehensive sense, argues Kant, must their conditioning postulates Time and Space be, to supply the "element," or "medium," that will render such pure percepts possible.

This doctrine of Kant's is certainly plausible; indeed, it is impressively so; and it has taken a vast hold in the world of science, and has reinforced the popular belief in the unreality of thought apart from Time and Space; an unreality which it is an essential part of Kant's system to establish critically. But as a graver result, it has certainly tended to discredit the belief in personal identity as an abiding and immutable reality, enthroned over the mutations of things in Time and Space; since all that is in these is numbered and is mutable, and is rather many than one, yet nothing is believed real except as it falls under them, at any rate under Time. And with this decline of the belief in a changeless self, has declined, almost as rapidly and extensively, the belief in immortality. Or, rather, the permanence and

the identity of the person has faded into a question regarded as unanswerable; though none the less does this agnostic state of belief tend to take personality, in any responsible sense of the word, out of the region of practical concern. With what is unknowable, even if existing, we can have no active traffic; 't is for our conduct as if it were not.

So it behooves us to search if this prevalent view about the relation of One and Many to Time and Space is trustworthy and exact. What place and function in philosophy must Space and Time be given?—for they certainly have a place and function; they certainly are among the inexpugnable conceptions with which thought has to concern itself when it undertakes to gain a view of the whole. But it may be easy to give them a larger place and function than belong to them by right. Is it true, then, that the One and the Many—that the system of Numbers, in short—are unthinkable except as in Space and Time, or, at any rate, in Time? Or, to put the question more exactly, as well as more gravely and more pertinently, Are Space and Time the true *principia individui,* and is Time preëminently the ultimate *principium individuationis?* Is there accordingly no individuality, and no society, no associative assemblage, except in the fleeting world of phenomena, dated and placed? Simply to ask the question, and thus bring out the full drift of this Kantian doctrine. is almost to expose the absurdity of it. Such a doctrine, though it may be wisely refusing to confound personality, true individuality, with the mere logical singular; nay, worse, with a limited and special illustration of the singular, the one *here* or the one *there,* the one *now* or the one *then;* nevertheless, by confining numerability to things material and sensible, makes personal identity something unmeaning or impossible, and destroys part of the foundation for the relations of moral responsi-

bility. Though the vital trait of the person, his genuine individuality, doubtless lies, not in his being exactly numerable, but in his being aboriginal and originative; in a word, in his self-activity, in his being a centre of autonomous social recognition; yet exactly numerable he indeed is, and must be, not confusable with any other, else his professed autonomy, his claim of rights and his sense of duty, can have no significance, must vanish in the universal confusion belonging to the indefinite. Nor, on the other hand, is it at all true that a number has to be a point or an instant, nor that things when numbered and counted are implicitly pinned upon points or, at all events, upon instants. It may well enough be the fact that in our empirical use of number we have to employ Time, or even Space, but it is a gaping *non sequitur* to conclude that we therefore can count nothing but the placed and the dated. Certainly we count whenever we *distinguish,*—by whatever means, on whatever ground. To think is, in general, at least to "distinguish the things that differ;" but this will not avail except we keep account of the differences; hence the One and the Many lie in the very bosom of intelligence, and this fundamental and spontaneous contrast can not only rive Time and Space into expressions of it, in instants and in points, but travels with thought from its start to its goal, and as organic factor in mathematical science does indeed, as Plato in the *Republic* said, deal with absolute being, if yet dreamwise; so that One and Many, and Many as the sum of the ones, makes part of the measure of that primally real world which the world of minds alone can be. If the contrast One and Many can pass the bounds of the merely phenomenal, by passing the temporal and the spatial; if it applies to universal being, to the noumenal as well as to the phenomenal; then the absolutely real world, so far as concerns this essential condition, can be a world of genuine

individuals, identifiable, free, abiding, responsible, and there can be a real moral order; if not, then there can be no such moral world, and the deeper thought-conceptions to which we now approach must be regarded, at the best, as fair illusions, bare ideals, which the serious devotee of truth must shun, except in such moments of vacancy and leisure as he may venture to surrender, at intervals, to purely hedonic uses. But if the One and the Many are not dependent on Time and Space, their universal validity is possible; and it has already been shown that they are not so dependent, are not thus restricted.

And now it remains to show their actual universality, by exhibiting their place in the structure of the absolutely real; since nobody calls in question their pertinence to the world of phenomena. But their noumenal applicability follows from their essential implication with all and every difference: no difference, no distinction, that does not carry counting; and this is quite as true as that there can be no counting without difference. The One and the Many thus root in Identity and Difference, pass up into fuller expression in Universal and Particular, hold forward into Cause and Effect, attain their commanding presentation in the Reciprocity of First Causes, and so keep record of the contrast between Necessity and Contingency. In short, they are founded in, and in their turn help (indispensably) to express, *all* the categories,—Quality, Quantity, Relation, Modality. Nor do they suffer arrest there; they hold in the ideals, the True, the Beautiful, the Good, and in the primary Ideas, the Self, the World, and God. For all of these differ, however close their logical linkage may be; and in so far as they differ, each of them is a counted unit, and so they are many. And, most profoundly of all, One and Many take footing in absolute reality so soon as we realize that nothing short of intelligent being can be primordially real,

underived, and truly causal, and that intelligence is, by its idea, at once an *I*-thinking and a universal recognizant outlook upon others that think *I*.

Hence Number, so far from being the derivative of Time and Space, founds, at the bottom, in the self-definition and social recognition of intelligent beings, and so finds *a priori* a valid expression in Time and in Space, as well as in every other primitive and spontaneous form in which intelligence utters itself. The Pythagorean doctrine of the rank of Number in the scale of realities is only one remove from the truth: though the numbers are indeed not the Prime Beings, they do enter into the essential nature of the Prime Beings; are, so to speak, the organ of their definite reality and identity, and for that reason go forward into the entire defining procedure by which these intelligences organize their world of experiences. And the popular impression that Time and Space are derivatives from Number, is in one aspect the truth, rather than the doctrine of Kant is; for though they are not mere generalizations and abstractions from numbered dates and durations, places and extents, they do exist as relating-principles which minds simply *put,* as the conditions *of perceptive experiences;* which by the nature of intelligence they must number in order to have and to master; while Number itself, the contrast of One and Many, enters into the very being of minds, and therefore still holds in Time and in Space, which are the organs, or *media,* not of the whole being of the mind, but only of that region of it constituted by sensation,—the material, the disjunct, the empirical. Besides, the logical priority of Number is implied in the fact that minds in putting Time and Space *a priori* must count them as two, since they discriminate them with complete clearness, so that it is impossible to work up Space out of Time (as Berkeley and Stuart Mill so adroitly, but so vainly, attempted to do),

or Time out of Space (as Hegel, with so little adroitness and such patent failure, attempted to do). No; there Time and Space stand, fixed and inconfusable, incapable of mutual transmutation, and thus the ground of an abiding difference between the inner of psychic sense-world and the outer or physical, between the subjective and the (sensibly) objective. By means of them, the world of minds discerns and bounds securely between the privacy of each and the publicity, the life "out of doors," which is common to all; between the cohering isolation of the individual and the communicating action of the society. Indeed, as from this attained point of view we can now clearly see, the real ground of the difference between Time and Space, and hence between subjective perception and the objective existence of physical things, is in the fact that a mind, in *being* such, —in its very act of self-definition,—correlates itself with a *society* of minds, and so, to fulfill its nature, in so far as this includes a world of experiences, must form its experience socially as well as privately, and hence will put forth a condition of sensuous communication, as well as a condition of inner sensation. Thus the dualization of the sense-world into inner and outer, psychic and physical, subjective and objective, rests at last on the intrinsically social nature of conscious being; rests on the twofold structure, logically dichotomous, of the self-defining act; and we get the explanation, from the nature of intelligence as such, why the Sense-Forms are necessarily two, and only two. It is no accident that we experience all things sensible in Time or in Space, or in both together; it is the natural expression of our primally intelligent being, concerned as that is, directly and only, with our self and its logically necessary complement, the other selves; and so that natural order, in its two discriminated but complemental portions, the inner and the outer, is founded in that moral order which

is given in the fundamental act of our intelligence. It is this resting of Space upon our veritable Objects, the Other Subjects, that imparts to it its externalizing quality, so that things in it are referred to the testing of all minds, not to ours only, and are reckoned external because measured by that which is alone indeed other than we.

In this way we may burst the restricting limit which so much of philosophy, and so much more of ordinary opinion, has drawn about our mental powers in view of this contrast Time and Space, especially with reference to the One and the Many, and to the persuasion that plural distinctions, at any rate, cannot belong in the region of absolute reality. Ordinary opinion either inclines to support a philosophy that is skeptical or either Unity or Plurality being pertinent beyond Time and Space, and thus to hold by agnosticism, or, if it affects affirmative metaphysics, tends to prefer monism to pluralism, when the number-category is carried up into immutable regions: to represent the absolutely real as One, somehow seems less contradictory of the "fitness of things" than to represent it as Many; moreover, carrying the Many into that supreme region, by implying the belonging there of morals such as we, seems shocking to customary piety, and full of extravagant presumption. Still, nothing short of this can really satisfy our deep demand for a moral order, a personal responsibility, nay, an adequate logical fulfillment of our conception of a self as an *intelligence;* while the clarification which a rational pluralism supplies for such ingrained puzzles in the theory of knowledge as that of the source and finality of the contrast Time and Space, to mention no others, should afford a strong corroborative evidence in its behalf. And, as already said, this view enables us to pass the limit which Time and Space are so often supposed to put, hopelessly, upon our concepts of the ideal grade, the springs of all our aspiration. To these, then, we may now pass.

We reach them through the doorways of the Necessary *vs.* the Contingent, the Unconditioned *vs.* the Conditioned, the Infinite *vs.* the Finite, the Absolute *vs.* the Relative; and we recognize them as our profoundest foundation-concepts, alone deserving, as Kant so pertinently said, the name of IDEALS,—the Soul, the World, and God. Associated with them are what we may call our three Forms of the Ideal,—the True, the Beautiful, the Good. These Ideas and their affiliated ideals have the highest directive and settling function in the organization of philosophy; they determine its schools and its history, by forming the centre of all its controlling problems; they prescribe its great subdivisions, breaking it up into Metaphysics, Æsthetics, and Ethics, and Metaphysics, again, into Psychology, Cosmology, and Ontology,—or Theology in the classic sense, which, in the modern sense, becomes the Philosophy of Religion; they call into existence, as essential preparatory and auxiliary disciplines, Logic and the Theory of Knowledge, or Epistemology. They thus provide the true distinctions between philosophy and the sciences of experience, and present these sciences as the carrying out, upon experiential details, of the methodological principles which philosophy alone can supply; hence they lead us to view all the sciences as in fact the applied branches, the completing organs of philosophy, instead of its hostile competitors.

As for the controlling questions which they start, these are such as follow: Are the ideals but bare ideals, serving only to cast "a light that never was, on land or sea?"—are the Ideals only bare ideas, without any objective being of their own, without any footing in the real, serving only to enhance the dull facts of experience with auroral illusions? The philosophic thinker answers affirmatively, or with complete skeptical dubiety, or with a convinced and uplifting

negative, according to his less or greater penetration into the real meaning of these deepest concepts, and depending on his view into the nature and thought-effect of the Necessary and the Contingent, the Unconditioned and the Conditioned, the Infinite and the Finite, the Absolute and the Relative.

And what, now, are the accurate, the adequate meanings of the three Ideas?—what *does* our profoundest thought intend by the Soul, by the World, by God? We know how Kant construed them, in consequence of the course by which he came critically (as he supposed) upon them,—as respectively the paramount Subject of Experiences; the paramount Object of experiences, or the Causal Unity of the possible series of sensible objects; and the complete Totality of Conditions for experience and its objects, itself therefore the Unconditioned. It is worth our notice, that especially by his construing the idea of God in this way, thus rehabilitating the classical and scholastic conception of God as the Sum of all Realities, he laid the foundation for that very transfiguration of mysticism, that idealistic monism, which he himself repudiated, but which his three noted successors in their several ways so ardently accepted, and which has since so pervaded the philosophic world. But suppose Kant's alleged critical analysis of the three Ideas and their logical basis is in fact far from critical, far from "exactly discriminative,"—and I believe there is the clearest warrant for declaring that it is,—then the assumed "undeniable critical basis" for idealistic monism will be dislodged, and it will be open to us to interpret the Ideas with accuracy and consistency—an interpretation which may prove to establish, not at all any monism, but a rational pluralism. And this will also reveal to us, I think, that our prevalent construing of the Unconditioned and the Conditioned, the Necessary and the Contingent, the Infinite and

the Finite, the Absolute and the Relative, suffers from an equal inaccuracy of analysis, and precisely for this reason gives a plausible but in fact untrustworthy support to the monistic interpretation of God, and Soul, and World; or, as Hegel and his chief adherents prefer to name them, God, Mind, and Nature. If the Kantian analysis stands, then it seems to follow, clearly enough, that God is the Inclusive Unit which at once embraces Mind and Nature, Soul and World, expresses itself in them, and imparts to them their meaning; and the plain dictate then is, that Kant's personal prejudice, and the personal prejudices of others like him, in favor of a transcendent God, must give way to that conception of the Divine, as immanent and inclusive, which is alone consistent with its being indeed the Totality of Conditions,—the Necessary Postulate, and the Sufficient Reason, for both Subject and Object.

But will Kant's analysis stand? Have we not here another of his few but fatal slips,—like his doctrine of the dependence of Number upon Time and Space, and its consequent subjection to them? It surely seems so. If the veritable postulate of categorical syllogizing be, as Kant thinks it is, merely the Subject, the self as experiencer of presented phenomena, in contrast to the Object, the causally united sum of possible phenomena; and if the true postulate of conditional syllogizing in this cosmic Object, as contrasted with the correlate Subject, then it would seem we cannot avoid certain pertinent questions. Is such a postulate Subject any fit and adequate account of the whole Self, of the Soul?—is there not a vital difference between this subject-self and the Self as Person?—does not Kant himself imply so, in his doctrine of the primacy of the Practical Reason? Again: Is not the World, as explained in Kant's analysis, and as afterwards made by him the solution of the Cosmological Antinomies, simply the supple-

mental factor necessarily correlate to the subjective aspect of the conscious life, and reduced from its uncritical rôle of thing-in-itself to the intelligible subordination required by Kant's theory of Transcendental Idealism?—and can this be any adequate account of the Idea that is to stand in sufficing contrast to the whole Self, the Person?—what less than the Society of Persons can meet the World-Idea for that? Further: If with Kant we take the World to mean no more than this object-factor in self-consciousness, must not the Soul, the total Self, from which, according to Kant's Transcendental Idealism, both Space and Time issue, supplying the basis for the immutable contrast between the experiencing subject and the really experienced objects,—must not this *whole* Self be the real meaning of the "Totality of Conditions, itself unconditioned," which comes into view as simply the postulate of disjunctive syllogizing? How in the world can disjunctive syllogizing, the confessed act of the *I*-thinking intelligence, really postulate anything as Totality of Conditions, in any other sense than the total of conditions for such syllogizing?—namely, the conditioning *I* that organizes and does the reasoning? There is surely no warrant for calling this total, which simply transcends and conditions the subject and the object of sensible experiences, by any loftier name than that which Kant had already given it in the Deduction of the Categories, when he designated it the "originally synthetic unity of apperception (self-consciousness)," or "the *I*-thinking *das ich-denke*) that must accompany all my mental presentations,"—that is to say, the whole Self, or thinking Person, idealistically interpreted. The use of the name of God in this connection, where Kant is in fact only seeking the roots of the three orders of the syllogism *when reasoning has by supposition been restricted to the subject-matter of experience,* is assuredly without warrant; yes, without ex-

cuse. In fact, it is because Kant sees that the third Idea, as reached through his analysis, is intrinsically immanent, —resident in the self that syllogizes disjunctively, and, because so resident, incapable of passing the bounds of possible experience,—while he also sees that the idea of God should mean a Being transcendent of every other thinker, himself a distinct individual consciousness, though not an empirically limited one,—it is, I say, precisely because he sees all this, that he pronounces the Idea, though named with the name of God, utterly without pertinence to indicate God's existence, and so enters upon that part of his Transcendental Dialectic which is, in chief, directed to exposing the transcendental illusion involved in the celebrated Ontological Proof. Consistently, Kant in this famous analytic of the syllogism should be talking, not of the Soul, the World, and God, but of the Subject (as uniting-principle of its sense-*perceptions*), the Object (as uniting-principle of all possible sense-*percepts*), and the Self (the whole *I* presiding over experience in both its aspects, as these are discriminated in Time and Space). By what rational title —even granting for the sake of argument that they are the genuine postulates of categorical and of conditional syllogizing—can this Subject and this Object, these correlate factors in the Self, rank as Ideas with the Idea of their conditioning Whole—the Self, that in its still unaltered identity fulfills, in Practical Reason, the high rôle of Person? If *this* no more than meets the standard of Idea, how can *they* meet it? How can two somethings, neither of which is the Totality of Conditions, and both of which are therefore in fact conditioned, deserve the same title with that which is intrinsically the Totality of Conditions, and, as such, unconditioned? To call the conditioned and the unconditioned alike Ideas is a confounding of dignities that Pure Reason should not tolerate, whether the procedure

be read as a leveling down or a leveling up. Distributing the titles conferred by Pure Reason in this democratic fashion reminds us too much, unhappily for Kant, of the Cartesian performances with Substance; whereby God, mind, and matter became alike "substances," though only God could in truth be said to "require nothing for his existence save himself," while mind and matter, though absolutely dependent on God, and derivative from him, were still to be called substances in the "modified" and Pickwickian sense of being underived from each other.

But if Kant's naming his third syllogistic postulate the Idea of God is inconsequent upon his analysis; or if, when the analysis is made consequent by taking the third Idea to mean the whole Self, the first and second postulates sink in conceptual rank, so that they cannot with any pertinence be called Ideas, unless we are willing to keep the same name when its meaning must be changed *in genere,*—a procedure that can only encumber philosophy instead of clearing its way,—these difficulties do not close the account; we shall find other curious things in this noted passage, upon which part of the characteristic outcome of Kant's philosophizing so much depends. Besides the misnaming of the third Idea, we have already had to question, in view of the path by which he reaches it, the fitness of his calling the first by the title of the Soul; and likewise, though for other and higher reasons of his calling the second by the name of the World. In fact, it comes home to us that all of the Ideas are, in one way or another, misnomers; Kant's whole procedure with them, in fine, has already appeared inexact, inconsistent, and therefore uncritical. But now we shall become aware of certain other inconsistencies. In coming to the Subject, as the postulate of categorical syllogizing, Kant, you remember, does so by the path of the relation Subject and Predicate, arguing that the chain of

categorical prosyllogisms has for its limiting concept and logical motor the notion of an absolute subject that cannot be a predicate; and as no subject of a judgment can of itself give assurance of fulfilling this condition, he concludes this motor-limit of judgment-subjects to be identical with the Subject as thinker, upon whom, at the last, all judgments depend, and who, therefore, and who alone, can never be a predicate merely. In similar fashion, he finds as the motor-limit of the series of conditional prosyllogisms, which is governed by the relation Cause and Effect, the notion of an absolute cause—a cause, that is, incapable of being an effect; and this, as undiscoverable in the chain of phenomenal causes, which are all in turn effects, he concludes is a pure Idea, the reason's native conception of a necessary linkage among all changes in Space, or of a Cosmic Unity among physical phenomena. In both conceptions, then, whether of the unity of the Subject or of the World, we seem to have a case of the unconditioned, as each, surely, is totally of conditions: the one, for all possible syllogisms by Subject and Predicate; the other, for all possible syllogisms from Cause and Effect. Until it can be shown that the syllogisms of the first sort and the syllogisms of the second are both conditioned by the system of disjunctive syllogisms, so that the Idea alleged to be the totality of conditions for this system becomes the conditioning principle for both the others, there appears to be no ground for contrasting the totality of conditions presented in it with those presented in the others, as if it were the absolute Totality of all Conditions, while the two others are only "relative totalities,"—which would be as much as to say they were only pseudo-totalities, both being conditioned instead of being unconditioned. But there seems to be no evidence, not even an indication, that disjunctive reasoning conditions categorical or conditional—that it constitutes the

whole kingdom, in which the other two orders of reasoning form dependent provinces, or that for final validation these must appeal to the disjunctive series and the Idea that controls it. On the contrary, any such relation seems disproved by the fact that the three types of syllogism apply alike in all subject-matter, psychic or physical, subjective or objective, concerning the Self or concerning the World,—yes, concerning other Selves or even concerning God; whereas, if the relation were a fact, it would require that only disjunctive reasoning can deal with the Unconditioned, and that conditional must confine itself to cosmic material, while categorical pertains only to the things of inner sense.

Such considerations cannot but shake our confidence in the inquisition to which Kant has submitted the Ideas of Reason, both as regards what they really mean and how they are to be correlated. At all events, the analysis of logical procedure and connection on which his account of them is based in full of the confusions and oversights that have now been pointed out, and justifies us in saying that his case is not established. Hence we are not bound to follow when his three successors, or their later adherents, proceed in acceptance of his results, and advance into various forms of idealism, all of the monistic type, as if the general relation between the three Ideas had been demonstrably settled by Kant in the monist sense, despite his not knowing this, and that all we have to do is to disregard his recorded protests, and render his results consistent, and our idealism "absolute," by casting out from his doctrine the distinction between the Theoretical and the Practical Reason, with the "primacy" of the latter, through making an end of his assumed world of *Dinge an sich,* or "things in themselves." This movement, I repeat, we are not bound to follow: a rectification of view as to the meaning of the three Ideas becomes possible as soon as we are freed from

Kant's entangled method of discovering and defining them; and when this rectification is effected, we shall find that the question between monism and rational or harmonic pluralism is at least open, to say no more. Nay, we are not to forget that by the results of our analysis of the concepts One and Many, Time and Space, and the real relation between them, plural metaphysics has already won a precedence in this contest.

THE DEVELOPMENT OF PHILOSOPHY IN THE NINETEENTH CENTURY

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The history of man's critical and reflective thought upon the more ultimate problems of nature and of his own life has, indeed, its period of quickened progress, relative stagnation, and apparent decline. Great thinkers are born and die, "schools of philosophy," so-called, arise, flourish, and become discredited; and tendencies of various characteristics mark the national or more general Zeitgeist of the particular centuries. And always, a certain deep undercurrent, or powerful stream of the rational evolution of humanity, flows silently onward. But these periods of philosophical development do not correspond to those which have been marked off for man by the rhythmic motion of the heavenly bodies, or by himself for purposes of greater convenience in practical affairs. The proposal, therefore, to treat any century of philosophical development as though it could be taken out of, and considered apart from, this constant unfolding of man's rational life is, of necessity, doomed to

failure. And, indeed, the nineteenth century is no exception to the general truth.

There is, however, one important and historical fact which makes more definite, and more feasible, the attempt to present in outline the history of the philosophical development of the nineteenth century. This fact is the death of Immanuel Kant, February 12, 1804. In a very unusual way this event marks the close of the development of philosophy in the eighteenth century. In a yet more unusual way the same event defines the beginning of the philosophical development of the nineteenth century. The proposal is, therefore, not artificial, but in accordance with the truth of history, if we consider the problems, movements, results, and present condition of this development, so far as the fulfillment of our general purpose is concerned, in the light of the critical philosophy of Kant. This purpose may then be further defined in the following way: to trace the history of the evolution of critical and reflective thought over the more ultimate problems of Nature and of human life, in the Western World during the last hundred years, and from the standpoint of the conclusions, both negative and positive, which are best embodied in the works of the philosopher of Königsberg. This purpose we shall try to fulfill in these four divisions of our theme; (1) A statement of the problems of philosophy as they were given over to the nineteenth century by the Kantian Critique; (2) a brief description of the lines of movement along which the attempts at the improved solution of these problems have proceeded, and of the principal influences contributing to these attempts; (3) a summary of the principal results of these movements—the items, so to say, of progress in philosophy which may be credited to the last century; and finally, (4) a survey of the present state of these problems as they are now to be handed down by the nineteenth to the

twentieth century. Truly an immensely difficult, if not an impossible task, is involved in this purpose!

I. The problems which the critical philosophy undertook definitely to solve may be divided into three classes. The first is the epistemological problem, or the problem offered by human knowledge—its essential nature, its fixed limitations, if such there be, and its ontological validity. It was this problem which Kant brought to the front in such a manner that certain subsequent writers on philosophy have claimed it to be, not only the primary and most important branch of philosophical discipline, but to comprise the sum-total of what human reflection and critical thought can successfully compass. "We call philosophy self-knowledge," says one of these writers. "The theory of knowledge is the true *prima philosophia*," says another. Kant himself regarded it as the most imperative demand of reason to establish a science that shall "determine *a priori* the possibility, the principles, and the extent of all cognitions." The burden of the epistemological problem has pressed heavily upon the thought of the nineteenth century; the different attitudes toward this problem, and its different alleged solutions, have been most influential factors in determining the philosophical discussions, divisions, schools, and permanent or transitory achievements of the century.

In the epistemological problem as offered by the Kantian philosophy of cognition there is involved the subordinate but highly important question as to the proper method of philosophy. Is the method of criticism, as that method was employed in the three Critiques of Kant, the exclusive, the sole appropriate and productive way of advancing human philosophical thought? I do not think that the experience of the nineteenth century warrants an affirmative answer to this question of method. This experience has certainly, however, resulted in demonstrating the need of a more

thorough, consistent, and fundamental use of the critical method than that in which it was employed by Kant. And this improved use of the critical method has induced a more profound study of the psychology of cognition, and of the historical development of philosophy in the branch of epistemology. More especially, however, it has led to the reinstatement of the value-judgments, as means of cognition, in their right relations of harmony with the judgments of fact and of law.

The second of the greater problems which the critical philosophy of the eighteenth handed on to the nineteenth century is the ontological problem. This problem, even far more than the espistemological, has excited the intensest interest, and called for the profoundest thought, of reflective minds during the last hundred years. This problem engages in the inquiry as to what Reality is; for to define philosophy from the ontological point of view renders it "the rational science of reality;" or, at least, "the science of the supreme and most important realities." In spite of the fact that the period immediately following the conclusion of the Kantian criticism was the age when the people were singing

"Da die Metaphysik vor Kurzem unbeerbt abging,
Werden die Dinge an sich jetzo sub hasta verkauft,"

the cultivation of the ontological problem, and the growth of systematic metaphysics in the nineteenth century, had never previously been surpassed. In spite of, or rather because of, the fact that Kant left the ancient body of metaphysics so dismembered and discredited, and his own ontological structure in such hopeless confusion, all the several buildings both of Idealism and of Realism either rose quickly or were erected upon the foundations made bare by the critical philosophy.

But especially unsatisfactory to the thought of the first quarter of the nineteenth century was the Kantian position with reference to the problem in which, after all, both the few who cultivate philosophy and the multitude who share in its fruits are always most truly interested; and this is the ethico-religious problem. In the judgment of the generation which followed him, Kant had achieved for those who accepted his points of view, his method of philosophizing, and his results, much greater success in "removing knowledge" than in "finding room for faith." For he seemed to have left the positive truths of Ethics so involved in the negative positions of his critique of knowledge as greatly to endanger them; and to have entangled the conceptions of religion with those of morality in a manner to throw doubt upon them both.

The breach between the human cognitive faculties and the ontological doctrines and conceptions on which morality and religion had been supposed to rest firmly, the elaborately argued distrust and skepticism which had been aimed against the ability of human reason to reached reality, and the consequent danger which threatened the most precious judgments of worth and the ontological value of ethical and æsthetical sentiments, could not remain unnoticed, or fail to promote ceaseless and earnest efforts to heal it. The hitherto accepted solutions of the problems of cognition, of being, and of man's ethico-religious experience, could not survive the critical philosophy. But the solutions which the critical philosophy itself offered could not fail to excite opposition and to stimulate further criticism. Moreover, certain factors in human nature, certain interests in human social life, and certain needs of humanity, not fully recognized and indeed scarcely noticed by criticism, could not fail to revive and to enforce their ancient, perennial, and valid claims.

In a word, Kant left the main problems of philosophy involved in numerous contradictions. The result of his penetrating but excessive analysis was unwarrantably to contrast sense with understanding; to divide reason as constitutive from reason as regulative; to divorce the moral law from our concrete experience of the results of good and bad conduct, true morality from many of the noblest desires and sentiments, and to set in opposition phenomena and noumena, order and freedom, knowledge and faith, science and religion. Now the highest aim of philosophy is reconciliation. What wonder, then, that the beginning of the last century felt the stimulus of the unreconciled condition of the problems of philosophy at the end of the preceding century! The greatest, most stimulating inheritance of the philosophy of the nineteenth century from the philosophy of the eighteenth century was the "post-Kantian problems."

II. The lines of the movement of philosophical thought and the principal contributory influences which belong to the nineteenth century may be roughly divided into two classes; namely, (1) those which tended in the direction of carrying to the utmost extreme the negative and destructive criticism of Kant, and (2) those which, either mainly favoring or mainly antagonizing the conclusions of the Kantian criticism, endeavored to place the positive answer to all three of these great problems of philosophy upon more comprehensive, scientifically defensible, and permanently sure foundations. The one class so far completed the attempt to remove the knowledge at which philosophy aims as, by the end of the first half of the century, to have left no rational ground for any kind of faith. The other class had not, even by the end of the second half of the century, as yet agreed upon any one scheme for harmonizing the various theories of knowledge, of reality, and of the ground of morality and religion. There appeared, however,—es-

specially during the last two decades of the century,—certain signs of convergence upon positions, to occupy which is favorable for agreement upon such a scheme, and which now promise a new constructive era for philosophy. The terminus of the destructive movement has been reached in our present-day positivism and philosophical skepticism. For this movement there would appear to be no more beyond in the same direction. The terminus of the other movement can only be somewhat dimly described. It may perhaps be predicted with a reasonable degree of confidence as some form of ontological Idealism (if we may use such a phrase) that shall be at once more thoroughly grounded in man's total experience, as interpreted by modern science, and also more satisfactory to human ethical, æsthetical, and religious ideals, than any form of systematic philosophy has hitherto been. But to say even this much is perhaps unduly to anticipate.

If we attempt to fathom and estimate the force of the various streams of influence which have shaped the history of the philosophical development of the nineteenth century, I think there can be no doubt that the profoundest and the most powerful is the one influence which must be recognized and reckoned with in all the centuries. This influence is humanity's undying interest in its moral, civil, and religious ideals, and in the civil and religious institutions which give a faithful but temporary expression to these ideals. In the long run, every fragmentary or systematic attempt at the solution of the problem of philosophy must sustain the test of an ability to contribute something of value to the realization of these ideals. The test which the past century has proposed for its own thinkers, and for its various schools of philosophy, is by far the severest which has ever been proposed. For the most part unostentatiously and in large measure silently, the thoughtful few and the comparatively

thoughtless multitude have been contributing either destructively or constructively, to the effort at satisfaction for the rising spiritual life of man. And if in some vague but impressive manner we speak of this thirst for spiritual satisfaction as characteristic of any period of human history, we may say, I believe, that it has been peculiarly characteristic and especially powerful as an influence during the last hundred years. The opinions, sentiments, and ideals which shape the development of the institutions of the church and state, and the freer activities of the same opinions, sentiments, and ideals, have been in this century, as they have been in every century, the principal factors in determining the character of its philosophical development.

But a more definite and visible kind of influence has constantly proceeded from the centres of the higher education. The universities—especially of Germany, next, perhaps of Scotland, but also of England and the United States, and even in less degree of France and Italy—have both fostered and shaped the evolution of critical and reflective thought, and of its product as philosophy. In Germany during the eighteenth century the greater universities had been emancipating themselves from the stricter forms of political and court favoritism and of ecclesiastical protection and control. This emancipation had already operated at the beginning of the nineteenth century, and it continued more and more to operate throughout this century, for participation in that free thought whose spirit is absolutely essential to the flourishing of true philosophy. All the other colleges and universities can scarcely repay the debt which modern philosophy owes to the universities of Germany. The institutions of the higher education which are moulded after this spirit, and which have a generous share of this spirit, have everywhere been *schools of thought* as well as schools of learning and research. Without the increasing

numbers and growing encouragement of such centres for the cultivation of the discipline of critical and reflective thinking, it is difficult to conjecture how much the philosophical development of the nineteenth century would have lost. *Libertas docendi* and *Academische Freiheit*—without these philosophy has one of its wings fatally wounded or severely clipped.

Not all the philosophy of the last century, however, was born and developed in academical centres and under academical influences. In Germany, Great Britain, and France, the various so-called "Academies" or other unacademical associations of men of scientific interests and attainments—notably, the Berlin Academy, which has been called "the seat of an anti-scholastic popular philosophy"—were during the first half of the nineteenth century contributing by their conspicuous failures as well as by their less conspicuous successes, important factors to the constructive new thought of the latter half of the nineteenth century. In general, although these men decried system and were themselves inadequately prepared to treat the problems of philosophy, whether from the historical or the speculative and critical point of view, they cannot be wholly neglected in estimating its development. Clever reasoning, and witty and epigrammatic writing on scientific or other allied subjects, cannot indeed be called *philosophy* in the stricter meaning of the word. But this so-called "popular philosophy" has greatly helped in a way to free thought from its too close bondage to scholastic tradition. And even the despite of philosophy, and sneering references to its "barrenness," which formerly charactertized the meetings and the writings of this class of its critics, but which now are happily much less frequent, have been on the whole both a valuable check and a stimulus to her devotees. He would be too narrow and sour a disciple of scholastic metaphysics and systematic philosophy

who, because of the levity or scorning of "outsiders," should refuse them all credit. Indeed, the lesson of the close of the nineteenth century may well enough be the motto for the beginning of the twentieth century: *In philosophy—since to philosophize is natural and inevitable for all rational beings—there really are no outsiders.*

In this connection it is most interesting to notice how men the type just referred to, were at the end of the eighteenth century found grouped around such thinkers as Mendelssohn, Lessing, F. Nicolai,—representing a somewhat decided reaction from the French realism to the German idealism. The work of the Academicians in the criticism of Kant was carried forward by Jacobi, who, at the time of his death, was the pensioned president of the Academy at Munich. Some of these same critics of the Kantian philosophy showed a rather decided preference for the "common-sense" philosophy of the Scottish School.

But both inside and outside of the Universities and Academies the scientific spirit and acquisitions of the nineteenth century have most profoundly, and on the whole favorably, affected the development of its philosophy. In the wider meaning of the word, "science,"—the meaning, namely, in which science=*Wissenschaft,*—philosophy aims to be scientific; and science can never be indifferent to philosophy. In their common aim at a rational and unitary system of principles, which shall explain and give its due significance to the totality of human experience, science and philosophy can never remain long in antagonism; they ought never even temporarily to be divided in interests, or in the spirit which leads each generously to recognize the importance of the other. The early part of the last century was, indeed, too much under the influence of that almost exclusively speculative *Natur-philosophie,* of which Schelling and Hegel were the most prominent exponents. On

the other hand, the conception of nature as a vast interconnected and unitary system of a rational order, unfolding itself in accordance with teleological principles,—however manifold and obscure,—is a noble conception and not destined to pass away.

On the continent—at least in France, where it had attained its highest development—the scientific spirit was, at the close of the eighteenth century, on the whole opposed to systematization. The impulse to both science and philosophy during both the eighteenth and the nineteenth centuries, over the entire continent of Europe, was chiefly due to the epoch-making work of that greatest of all titles in the modern scientific development of the Western World, the *Principia* of Newton. In mathematics and the physical sciences, during the early third or half of the last century, Great Britain also has a roll of distinguished names which compares most favorably with that of either France or Germany. But in England, France, and the United States, during the whole century, science has lacked the breadth and philosophic spirit which it had in Germany during the first three quarters of this period. During all that time the German man of science was, as a rule, a scholar, an investigator, a teacher, *and a philosopher.* Science and philosophy thrived better, however, in Scotland than elsewhere outside of Germany, so far as their relations in interdependence were concerned. Into the Scottish universities Playfair introduced some of the continental suggestions toward the end of the eighteenth century, so that there was less of exclusiveness and unfriendly rivalry between science and philosophy; and both profited thereby. In the United States, during the first half or more of the century, so dominant were the theological and practical interests and influences that there was little free development of either science or philosophy,—if we interpret

the one as the equivalent of *Wissenschaft* and understand the other in the stricter meaning of the word.

The history of the development of the scientific spirit and of the achievements of the particular sciences is not the theme of this paper. To trace in detail, or even in its large outlines, the reciprocal influence of science and philosophy during the past hundred years, would itself require far more than the space allotted to me. It must suffice to say that the various advances in the efforts of the particular sciences to enlarge and to define the conceptions and principles employed to portray the Being of the World in its totality, have somewhat steadily grown more and more completely metaphysical, and more and more of positive importance for the reconstruction of systematic philosophy. The latter has not simply been disciplined by science, compelled to improve its method, and to examine all its previous claims. But philosophy has also been greatly enriched by science with respect to its material awaiting synthesis, and it has been not a little profited by the unsuccessful attempts of the current scientific theories to give themselves a truly satisfactory account of that Ultimate Reality which, to understand the better, is no unworthy aim of their combined efforts.

During the nineteenth century science has seen many important additions to that Ideal of Nature and her processes, to form which in a unitary and harmonizing but comprehensive way is the philosophical goal of science. The gross mechanical conception of nature which prevailed in the earlier part of the eighteenth century has long since been abandoned, as quite inadequate to our experience with her facts, forces, and laws. The kinetic view, which began with Huygens, Euler, and Ampère, and which was so amplified by Lord Kelvin and Clerk-Maxwell in England, and by Helmholtz and others in Germany, on account of its suc-

cess in explaining the phenomena of light, of gases, etc., very naturally led to the attempt to develop a kinetic theory, a doctrine of energetics, which should explain all phenomena. But the conception of "that which moves," the experience of important and persistent qualitative *differentiae,* and the need of assuming ends and purposes served by the movement, are troublesome obstacles in the way of giving such a completeness to this theory of the Being of the World. Yet again the amazing success which the theory of evolution has shown in explaining the phenomena with which the various biological sciences concern themselves, has lent favor during the latter half of the century to the vitalistic and genetic view of nature. For all our most elaborate and advanced kinetic seem utterly to fail us as explanatory when we, through the higher powers of the microscope, stand wondering and face to face with the evolution of a single living cell. But from such a view of the essential Being of the World as evolution suggests to the psycho-physical theory of nature is not an impassable gulf. And thus, under its growing wealth of knowledge, science may be leading up to an Ideal of the Ultimate Reality, in which philosophy will gratefully and gladly coincide. At any rate, the modern conception of nature and the modern conception of God are not so far apart from each other, as either of these conceptions is now removed from the conceptions covered by the same terms, some centuries gone by.

There is one of the positive sciences, however, with which the development of philosophy during the last century has been particularly allied. This science is psychology. To speak of its history is not the theme of this paper. But it should be noted in passing how the development of psychology has brought into connection with the physical and biological sciences the development of philosophy. This

union, whether it be for better or for worse,—and, on the whole, I believe it to be for better than for worse,—has been in a very special way the result of the last century. In tracing its details we should have to speak of the dependence of certain branches of psychology on physiology, and upon Sir Charles Bell's discovery of the difference between the sensory and the motor nerves. This discovery was the contribution of the beginning of the century to an entire line of discoveries, which have ended at the close of the century with putting the localization of cerebral function upon a firm experimental basis. Of scarcely less importance has been the cellular theory as applied (1838) by Matthias Schleiden, a pupil of Fries in philosophy, to plants, and by Theodor Schwann about the same time to animal organisms. To these must be added the researches of Johannes Müller (1801-1858), the great biologist, a listener to Hegel's lectures, whose law of *specific energies* brings him into connection with psychology and, through psychology, to philosophy. Even more true is this of Helmholtz, whose *Lehre von den Tonempfindungen* (1862) and *Physiologische Optik* (1867) placed him in even closer, though still mediate, relations to philosophy. But perhaps especially Gustav Theodor Fechner (1801-1887), whose researches in psycho-physics laid the foundations of whatever, either as psychology or as philosophy, goes under this name; and whether the doctrine have reference to the relation of man's mind and body, or to the wider relations of spirit and matter.

In my judgment it cannot be affirmed that the attempts of the latter half of the nineteenth century to develop an experimental science of psychology in independence of philosophical criticism and metaphysical assumption, or the claims of this science to have thrown any wholly new light upon the statement, or upon the solution of philosophical

problems, have been largely successful. But certain more definitely psychological questions have been to a commendable degree better analyzed and elucidated; the new experimental methods, where confined within their legitimate sphere, have been amply justified; and certain *quasi*-metaphysical views respecting the nature of the human mind, and even, if you will, the nature of the Spirit in general—have been placed in a more favorable and scientifically engaging attitude toward speculative philosophy. This seems to me to be especially true with respect to two problems in which both empirical psychology and philosophy have a common and profound interest. These are (1) the complex synthesis of mental functions involved in every act of true cognition, together with the bearing which the psychology of cognition has upon epistemological problems; and (2) the yet more complex and profound analysis, from the psychological point of view, of what it is to be a self-conscious and self-determining Will, a true Self, together with the bearing which the psychology of selfhood has upon all the problems of ethics, æsthetics, and religion.

The more obvious and easily traceable influences which have operated to incite and direct the philosophical development of the nineteenth century are, of course, dependent upon the teachings and writings of philosophers, and the schools of philosophy which they have founded. To speak of these influences even in outline would be to write a manual of the history of philosophy during that hundred of years, which has been of all others by far the most fruitful in material results, whatever estimate may be put upon the separate or combined values of the individual thinkers and their so-called schools. No fewer than seven or eight relatively independent or partially antagonistic movements, which may be traced back either directly or more indirectly to the critical philosophy, and to the form in which

the problems of philosophy were left by Kant, sprung up during the century. In Germany chiefly, there arose the Faith-philosophy, the Romantic School, and Rational Idealism; in France, Eclecticism and Positivism (if, indeed, the latter can be called *a* philosophy); in Scotland, a naïve and crude form of Realism, which served well for the time as an antagonist of a skeptical idealism, but which itself contributed to an improved form of Idealism; and in the United States, or rather in New England, a peculiar kind of Transcendentalism of the sentimental type. But all these movements of thought, and others lying somewhere midway between, in a pair composed of any two, together with a steadfast remainder of almost every sort of Dogmatism, and all degrees and kinds of Skepticism, have been intermixed and contending with one another, in all these countries. Such has been the varied, undefinable, and yet intensely stimulating and interesting character of the development of systematic and scholastic philosophy, during the nineteenth century.

The early opposition to Kant in Germany was, in the main, two-fold:—both to his peculiar extreme analysis with its philosophical conclusions, and also to all systematic as distinguished from a more popular and literary form of philosophizing. Toward the close of the eighteenth century a group of men had been writing upon philosophical questions in a spirit and method quite foreign to that held in respect by the critical philosophy. It is not wholly without significance that Lessing, whose aim had been to use common sense and literary skill in clearing up obscure ideas and improving and illumining the life of man, died in the very year of the appearance of Kant's *Kritik der reinen Vernunft*. Of this class of men an historian dealing with this period has said, "There is hardly one who does not quote somewhere or other Pope's saying, 'The proper study

of mankind is man.' " To this class belong Hamann (1730-1788), the inspirer of Herder and Jacobi. The former, who was essentially a poet and a friend of Goethe, controverted Kant with regard to this doctrine of reason, his antithesis between the individual and the race, and his schism between things as empirically known and the known unity in the Ground of their being and becoming. Herder's path to truth was highly colored with flowers or rhetoric; but the promise was that he would lead men back to the heavenly city. Jacobi, too, with due allowance made for the injury wrought by his divorce of the two philosophies,—that of faith and that of science,—and his excessive estimate of the value-judgments which repose in the midst of a feeling-faith, added something of worth by way of exposing the barrenness of the Kantian doctrine of an unknowable "Thing-in-itself."

From men like Fr. Schlegel (1772-1829), whose valid protest against the sharp separation of speculative philosophy from the æsthetical, social, and ethical life, assumed the "standpoint of irony," little real result in the discovery of truth could be expected. But Schleiermacher (1768-1834), in spite of that mixture of unfused elements which has made his philosophy "a rendezvous for the most diverse systems," contributed valuable factors to the century's philosophical development, both of a negative and of a positive character. This thinker was peculiarly fortunate in the enrichment of the conception of experience as warranting a justifiable confidence in the ontological value of ethical, æsthetical, and religious sentiment and ideas; but he was most unfortunate in reviving and perpetuating the unjustifiable Kantian distinction between cognition and faith in the field of experience. On the whole, therefore, the Faith-philosophy and the Romantic School can easily be said to have contributed more than a negative and modifying in-

fluence to the development of the philosophy of the nineteenth century. Its more modern revival toward the close of the same century, and its continued hold upon certain minds of the present day, are evidences of the positive but partial truth which its tenets, however vaguely and unsystematically, continue to maintain in an æsthetically and practically attractive way.

The admirers of Kant strove earnestly and with varied success to remedy the defects of his system. Among the earlier, less celebrated and yet important members of this group, were K. G. Reinhold (1758-1823), and Maimon (died, 1800). The former, like Descartes, in that he was educated by the Jesuits, began the attempt, after rejecting some of the arbitrary distinctions of Kant and his barren and self-contradictory "Thing-in-itself," to unify the critical philosophy by reducing it to some one principle. The latter really transcended Kant in his philosophical skepticism, and anticipated the Hamiltonian form of the so-called principle of relativity. Fries (1773-1843), and Hermes (1775-1831)—the latter of whom saw in empirical psychology the only true propædeutic to philosophy—should be mentioned in this connection. In the same group was another, both mathematician and philosopher, who strove more successfully than others of this group to accept the critical standpoint of Kant and yet to transcend his negative conclusions with regard to a theory of knowledge. I refer to Bolzano (Prague, 1781-1848), who stands in the same line of succession with Fries and Hermes, and whose works on the *Science of Religion* (4 vols. 1834) and his *Science of Knowledge* (4 vols. 1837) are noteworthy contributions to epistemological doctrine. In the latter we have developed at great length the important thought that the illative character of propositional judgments implies an objective relation; and that in all truths the subject-idea

must be objective. In the work on religion there is found as thoroughly dispassionate and rational a defense of Catholic doctrine as exists anywhere in philosophical literature. The limited influence of these works, due in part to their bulk and their technical character, is on the whole, I think, sincerely to be regretted.

It was, however, chiefly that remarkable series of philosophers which may be grouped under the rubric of a "rational Idealism," who filled so full and made so rich the philosophical life of Germany during the first half of the last century; whose philosophical thoughts and systems have spread over the entire Western World, and who are most potent influences in shaping the development of philosophy down to the present hour. Of these we need do little more than that we can do—mention their names. At their head, in time, stands Fichte, who—although Kant is reported to have complained of this disciple because he lied about him so much—really divined a truth which seems to be hovering in the clouds above the master's head, but which, if the critical philosophy truly meant to teach it, needed helpful deliverance in order to appear in perfectly clear light. Fichte, although he divined this truth, did not, however, free it from internal confusion and self-contradiction. It *is* his truth, nevertheless, that in the Self, as a self-positing and self-determining activity, must somehow be found the Ground of all experience and of all Reality.

The important note which Schelling sounded was the demand that philosophy should recognize "Nature" as belonging to the sphere of Reality, and as requiring a measure of reflective thought which should in some sort put it on equal terms with the Ego, for the construction of our conception of the Being of the World. To Schelling it seemed impossible to deduce, as Fichte had done, all the rich concrete development of the world of things from the sub-

jective needs and constitutional forms of functioning which belong to the finite Self. And, indeed, the doctrine which limits the origin, existence, and value of all that is known about this sphere of experience to these needs, and which finds the sufficient account of all experience with nature in these forms of functioning, must always seem inadequate and even grotesque in the sight of the natural sciences. Both Nature and Spirit, thought Schelling, must be allowed to claim actual existence and equally real value; while at the same time philosophy must reconcile the seeming opposition of their claims and unite them in an harmonious and self-explanatory way. In some common substratum, in which, to adopt Hegel's sarcastic criticism, as in the darkness of the night "all cows are black,"—that is in the Absolute, as an Identical Basis of Differences,—the reconciliation was to be accomplished.

But the constructive idealistic movement, in which Fichte and Schelling bore so important a part, could not be satisfied with the positions reached by either of these two philosophers. Neither the physical and psychological sciences, nor the speculative interests of religion, ethics, art, and social life, permitted this movement to stop at this point. In all the subsequent developments of philosophy during the first half or three quarters of the nineteenth century, undoubtedly the influence of Hegel was greatest of all individual thinkers. His *motif* and plan are revealed in his letter of November 2, 1800, to Schelling, namely, to transform what had hitherto been an ideal into a thoroughly elaborate system. And in spite of his obvious obscurities of thought and style, there is real ground for his claim to be the champion of the common consciousness. It is undoubtedly in Hegel's *Phänomenologie des Geistes* (1807), that the distinctive features of the philosophy of the first half of the last century most clearly define themselves. The

forces of reflection now abandon the abstract analytic method and positions of the Kantian Critique, and concentrate themselves upon the study of man's spiritual life as an historical evolution, in a more concrete, face-to-face manner. Two important and, in the main, valid assumptions underlie and guide this reflective study: (1) The Ultimate Reality, or principle of all realities, is Mind or Spirit, which is to be recognized and known in its essence, not by analysis into its formal elements (the categories), but as a living development; (2) those formal elements, or categories to which Kant gave validity merely as constitutional forms of the functioning of the human understanding, represent, the rather, the essential structure of Reality.

In spite of these true thoughts, fault was justly found by the particular sciences with both the speculative method of Hegel, which consists in the smooth, harmonious, and systematic arrangement of conceptions in logical or ideal relations to one another; and also with the result, which reduces the Being of the World to terms of thought and dialectical processes merely, and neglects or overlooks the other aspects of racial experience Therefore, the idealistic movement could not remain satisfied with the Hegelian dialectic. Especially did both the religious and the philosophical party revolt against the important thought underlying Hegel's philosophy of religion; namely, that "the more philosophy approximates to a complete development, the more it exhibits the same need, the same interest, and the same content, as religion itself." This, as they interpreted it, meant the absorption of religion in philosophy.

Next after Hegel, among the great names of this period, stand the names of Herbart and Schopenhauer. The former contributes in an important way to the proper conception of the task and the method of philosophy, and influences greatly the development of psychology, both as a

science that is pedagogic to philosophy, and as laying the basis for pedogogical principles and practice. But Herbart commits again the ancient fallacy, under the spell of which so much of the Kantian criticism was bound, and which identifies contradictions that belong to the imperfect or illusory conceptions of individual thinkers with insoluble antinomies inherent in reason itself. In spite of the little worth and misleading character of his view of perception, and the quite complete inadequacy of the method by which, at a single leap, he reaches the one all-explanatory principle of his philosophy, Schopenhauer made a most important contribution to the reflective thought of the century. It is true, as Kuno Fischer has said, that it seems to have occurred to Schopenhauer only twenty-five years after he had propounded his theory, that will, as it appears in consciousness, is as truly phenomenal as is intellect. It is also true that his theory of knowledge and his conception of Reality, as measured by their power to satisfy and explain our total experience, are inflicted with irreconcilable contradictions. Neither can we accord firm confidence or high praise to the "Way of Salvation" which somehow Will can attain to follow by æsthetic contemplation and ascetic self-denial. Yet the philosophy of Schopenhauer rightly insists upon our Idealistic construction of Reality having regard to aspects of experience which his predecessors had quite too much neglected; and even its spiteful and exaggerated reminders of the facts which contradict the tendency of all Idealism to construct a smooth, regular, and altogether pleasing conception of the Being of the World, have been of great benefit to the development of the latter half of the nineteenth century.

In estimating the thoughts and the products of modern Idealism we ought not to forget the larger multitude of thoughtful men, both in Germany and elsewhere, who have

contributed toward shaping the course of reflection in the attempt to answer the problems which the critical philosophy left to the nineteenth century. It is a singular comment upon the caprices of fame that, in philosophy as in science, politics, and art, some of those who have really reasoned most soundly and acutely, if not also effectively upon these problems, are little known even by name in the history of the philosophical development of the century. Among the earlier members of this group, did space permit, we should wish to mention Berger, Solger, Steffens, and others, who strove to reconcile the positions of a subjective idealism with a realistic but pantheistic conception of the Being of the World. There are others, who like Weisse, I. H. Fichte, C. P. Fischer, and Braniss, more or less bitterly or moderately and reasonably, opposed the method and the conclusions of the Hegelian dialectic. Still another group earned for themselves the supposedly opprobious but decidedly vague title of "Dualists," by rejecting what they conceived to be the pantheism of Hegel. Still others, like Fries and Beneke and their successors, strove to parallel philosophy with the particular sciences by grounding it in an empirical but scientific psychology; and thus they instituted a line of closely connected development, to which reference has already been made.

Hegel himself believed that he had permanently effected that reconciliation of the orthodox creed with the cognition of Ultimate Reality at which his dialectic aimed. In all such attempts at reconciliation three great questions are chiefly concerned: (1) the Being of God; (2) the nature of man; (3) the actual and the ideally satisfactory relations between the two. But, as might have been expected, a period of wild, irregular, and confused contention met the attempt to establish this claim. In this conflict of more or less noisy and popular as well as of thoughtful and scholas-

tic philosophy, Hegelians of various degrees of fidelity, anti-Hegelians of various degrees of hostility, and ultra-Hegelians of various degrees of eccentricity, all took a valiant and conspicuous part. We cannot follow its history; but we can learn its lesson. Polemical philosophy, as distinguished from quiet, reflective, and critical but constructive philosophy involves a most uneconomical use of mental force. Yet out of this period of conflict, and in a measure as its result, there came a period of improved relations between science and philosophy and between philosophy and theology, which was the dawn, toward the close of the nineteenth century, of that better illumined day into the middle of which we hope that we are proceeding.

Before leaving this idealistic movement in Germany, and elsewhere as influenced largely by German philosophy, one other name deserves mention. This name is that of Lotze, who combined elements from many previous thinkers with those derived from his own studies and thoughts,—the conceptions of mechanism as applied to physical existences and to psychical life, with the search for some monistic Principle that shall satisfy the æsthetical and ethical, as well as the scientific demands of the human mind. This variety of interests and of culture led to the result of his making important contributions to psychology, logic, metaphysics, and æsthetics. If we find his system of thinking —as I think we must—lacking in certain important elements of consistency and obscured in places by doubts as to his real meaning, this does not prevent us from assigning to Lotze a position which, for versatility of interests, genial quality of reflection and criticism, suggestiveness of thought and charm of style, is second to no other in the history of nineteenth century philosophical development.

In France and in England the first quarter of the last century was far from being productive of great thinkers

or great thoughts in the sphere of philosophy. De Biran (1766-1824), in several important respects the forerunner of modern psychology, after revolting from his earlier complacent acceptance of the vagaries of Condillac and Cabanis, made the discovery that the "immediate consciousness of self-activity is the primitive and fundamental principle of human cognition." Meantime it was only a little group of Academicians who were being introduced, in a somewhat superficial way, to the thoughts of the Scottish and the German idealistic Schools by Roger-Collard, Jouffroy, Cousin, and others. A more independent and characteristic movement was that inaugurated by Auguste Comte (1798-1857), who, having felt the marked influence of Saint-Simon when he was only a boy of twenty, in a letter to his friend Valat, in the year 1824, declares: "I shall devote my whole life and all my powers to the founding of positive philosophy." In spite of the impossibility of harmonizing with this point of view the vague and mystical elements which characterize the later thought of Comte, or with its carrying into effect the not altogether intelligent recognition of the synthetic activity of the mind (*tout se réduit toujours à lier*) and certain hints as to "first principles;" and in spite of the small positive contribution to philosophy which Comtism could claim to have made; it has in a way represented the value of two ideas. These are (1) the necessity for philosophy of studying the actual historical forces which have been at work and which are displayed in the facts of history; and (2) the determination not to go by mere unsupported speculation beyond experience in order to discover knowable Reality. There is, however, a kind of subtle irony in the fact that the word "Positivism" should have come to stand so largely for *negative* conclusions, in the very spheres of philosophy, morals, and religion where *affirmative* conclusions are so much desired and sought.

That philosophy in Great Britain was in a nearly complete condition of decadence during the first half or three quarters of the nineteenth century was the combined testimony of writers from such different points of view as Carlyle, Sir William Hamilton, and John Stuart Mill. And yet these very names are also witnesses to the fact that this decadence was not quite complete. In the first quarter of the century Coleridge, although he had failed, on account of weakness both of mind and of character, in his attempt to reconcile religion to the thought of his own age, on the basis of the Kantian distinction between reason and the intellect, had sowed certain seed-thoughts which became fertile in the soil of minds more vigorous, logical, and practical than his own. This was, perhaps, especially true in America, where inquirers after truth were seeking for something more satisfactory than the French skepticism of the revolutionary and following period. Carlyle's mocking sarcasm was also not without wholesome effect.

But it was Sir William Hamilton and John Stuart Mill whose thoughts exercised a more powerful formative influence over the minds of the younger men. The one was the flower of the Scottish Realism, the other of the movement started by Bentham and the elder Mill.

That the Scottish Realism should end by such a combination with the skepticism of the critical philosophy as is implied in Hamilton's law of the relativity of all knowledge, is one of the most curious and interesting turns in the history of modern philosophy. And when this law was so interpreted by Dean Mansel in its application to the fundamental cognitions of religion as to lay the foundations upon which the most imposing structure of agnosticism was built by Herbert Spencer, surely the entire swing around the circle, from Kant to Kant again, has been made complete. The attempt of Hamilton failed, as every similar

attempt must always fail. Neither speculative philosophy nor religious faith is satisfied with an abstract conception, about the correlate of which in Reality nothing is known or ever can be known. But every important attempt of this sort serves the double purpose of stimulating other efforts to reconstruct the answer to the problem of philosophy, on a basis of positive experience of an enlarged type; and also of acting as a real, if only temporary practical support to certain value-judgments which the faiths of morality, art, and religion both implicate and, in a measure, validate.

The influence of John Stuart Mill, as it was exerted not only in his conduct of life while a servant of the East India Company, but also in his writings on Logic, Politics, and Philosophy, was, on the whole, a valuable contribution to his generation. In the additions which he made to the Utilitarianism of Bentham we have done, I believe, all that ever can be done in defense of this principle of ethics. And his posthumous confessions of faith in the ontological value of certain great conceptions of religion are the more valuable because of the nature of the man, and of the experience which is their source. Perhaps the most permanent contribution which Mill made to the development of philosophy proper, outside of the sphere of logic, ethics, and politics, was his vigorous polemical criticism of Hamilton's claim for the necessity of faith in an "Unconditioned" whose conception is "only a fasciculus of negations of the Conditioned in its opposite extremes, and bound together merely by the aid of language and their common character of incomprehensibility."

The history of the development of philosophy in America during the nineteenth century, as during the preceding century, has been characterized in the main by three principal tendencies. These may be called the theological, the social,

and the eclectic. From the beginning down to the present time the religious influence and the interest in political and social problems have been dominant. And yet withal, the student of these problems in the atmosphere of this country likes, in a way, to do his own thinking and to make his own choices of the thoughts that seem to him true and best fitted for the best form of life. In spite of the fact that the different streams of European thought have flowed in upon us somewhat freely, there has been comparatively little either of the adherence to schools of European philosophy or of the attempt to develop a national school. Doubtless the influence of English and Scottish thinking upon the academical circles of America was greatest for more than one hundred and fifty years after the gift in 1714 by Governor Yale of a copy of Locke's Essay to the college which bore his name,—and especially upon the reflections and published works of Jonathan Edwards touching the fundamental problems of epistemology, ethics, and religion. During the early part of this century these views awakened antagonism from such writers as Dana, Whedon, Hazard, Nathaniel Taylor, Jeremiah Day, Henry P. Tappan, and other opponents of the Edwardean theology, and also from such advocates of so-called "free-thinking," as had derived their *motifs* and their views from English deistical writers like Shaftesbury, or from the skepticism of Hume.

A more definite philosophical movement, however, which had established itself somewhat firmly in scholastic centres by the year 1825, and which maintained itself for more than half a century, went back to the arrival in this country of John Witherspoon, in 1768, to be the president of Princeton, bringing with him a library of three hundred books. It was the appeal of the Scottish School to the "plain man's consciousness" and to so-called "common

sense," which was relied upon to controvert all forms of philosophy which seemed to threaten the foundations of religion and of the ethics of politics and sociology. But even during this period, which was characterized by relatively little independent thinking in scholastic circles, a more pronounced productivity was shown by such writers as Francis Wayland, and others; but, perhaps, especially by Laurens P. Hickok, whose works on psychology and cosmology deserve especial recognition: while in psychology, as related to philosophical problems, the principal names of this period are undoubtedly the presidents of Yale and Princeton,—Noah Porter and James McCosh,—both of whom (but especially the former) had their views modified by the more scientific psychology of Europe and the profounder thinking of Germany.

It was Germany's influence, however, both directly and indirectly through Coleridge and a few other English writers, that caused a ferment of impressions and ideas which, in their effort to work themselves clear, resulted in what is known as New England "Transcendentalism." In America this movement can scarcely be called definitely philosophical; much less can it be said to have resulted in a system, or even in a school, of philosophy. It must also be said to have been "inspired but not borrowed" from abroad. Its principal, if not sole, literary survival is to be found in the works of Emerson. As expounded by him, it is not precisely Pantheism—certainly not a consistent and critical development of the pantheistic theory of the Being of the World; it is, rather, a vague, poetical, and pantheistical Idealism of a decidedly mystical type.

The introduction of German philosophy proper, in its nature form, and essential being, to the few interested seriously in critical and reflective thinking upon the ultimate problems of nature and of human life, began with the

founding of the *Journal of Speculative Philosophy,* in 1867, under the direction of William T. Harris, then Superintendent of Schools in this city.

With the work of Darwin, and his predecessors and successors, there began a mighty movement of thought which, although it is primarily scientific and more definitely available in biological science, has already exercised, and is doubtless destined to exercise in the future, an enormous influence upon philosophy. Indeed, we are already in the midst of the preliminary confusions and contentions, but most fruitful considerations and discoveries belonging to a so-called philosophy of evolution.

This development has, in the sphere of systematic philosophy, reached its highest expression in the voluminous works produced through the latter half of the nineteenth century by Mr. Herbert Spencer, whose recent death seems to mark the close of the period we have under consideration. The metaphysical assumptions and ontological value of the system of Spencer, as he wished it to be understood and interpreted, have perhaps, though not unnaturally, been quite too much submerged in the more obvious expressions of its agnostic positivism. In its psychology, however, the assumption of "some underlying substance in contrast to all changing forms," distinguishes it from a pure positivism in a very radical way. But more especially in philosophy, the metaphysical postulate of a mysterious Unity of Force that somehow manages to reveal itself, and the law of its operations, to the developed cognition of the nineteenth century philosopher, however much it seems to involve the system in internal contradictions, certainly forbids that we should identify it with the positivism of Auguste Comte. In our judgment, however, it is in his ethical good sense and integrity of judgment,—a good sense and integrity which commits to ethics rather than to sociology the task of de-

termining the highest type of human life,—and in basing the conditions for the prevalence and the development of the highest type of life upon ethical principles and upon the adherence to ethical ideas, that Herbert Spencer will be found most clearly entitled to a lasting honor.

III. The third number of our difficult tasks is to summarize the principal results, to inventory the net profits, as it were, of the development of philosophy during the nineteenth century. This task is made the more difficult by the heterogeneous nature and as yet unclassified condition of the development. With the quickening and diversifying of all kinds and means of intercourse, there has come the breaking-down of national schools and idiosyncrasies of method and of thought. In philosophy, Germany, France, Great Britain, and indeed, Italy, have come to intermingle their streams of influence; and from all these countries these streams have been flowing in upon America. In psychology, especially, as well as in all the other sciences, but also to some degree in philosophy, returning streams of influence from America have, during the last decade or two, been felt in Europe itself.

It must also be admitted that the attempts at a reconstruction of systematic philosophy which have followed the rapid disintegration of the Hegelian system, and the enormous accumulations of new material due to the extension of historical studies and of the particular sciences,—including especially the so-called "new psychology,"—have not as yet been fruitful of large results. In philosophy, as in art, politics, and even scientific theory, the spirit and the opportunity of the time are more favorable to the gathering of material and to the projecting of a bewildering variety of new opinions, or old opinions put forth under new names, than to that candid, patient, and prolonged reflection and balancing of judgment which a worthy system-building in-

exorably requires. The age of breaking up the old, without assimilating the new, has not yet passed away. And whatever is new, startling, large, even monstrous, has in many quarters the seeming preference, in philosophy's building as in other architecture. To the confusion which reigns even in scholastic circles, contributions have been arriving from the outside, from philosophers like Nietzsche, and from men great in literature like Tolstoi. Nor has the matter been helped by the more recent extreme developments of positivism and skepticism, which often enough, without any consciousness of their origin and without the respect for morality and religion which Kant always evinced, really go back to the critical philosophy.

In spite of all this, however, the last two decades or more have shown certain hopeful tendencies and notable achievements, looking toward the reconstruction of systematic philosophy. In this attempt to bring order out of confusion, to enable calm, prolonged, and reflective thinking to build into its structure the riches of the new material which the evolution of the race has secured, a place of honor to be given to France, where so much has been done of late to blend with clearness of style and independence of thought that calm reflective and critical judgment which looks all sides of human experience sympathetically but bravely in the face. In psychology Ribot, and in philosophy Fouillée, Renouvier, Secrétan, and others, deserve grateful recognition. No friend of philosophy can, I think, fail to recognize the probable benefits to be derived from that movement with which such names as Mach and Ostwald in Germany are connected, and which is sounding the call to the men of science to clear up the really distressing obscurity and confusion which has so long clung to their fundamental conceptions; and to examine anew the significance of their assumptions, with a view to the construction of a new and

improved doctrine of the Being of the World. And if to these names we add those of the numerous distinguished investigators of psychology as pedagogic to philosophy, and, in philosophy, of Deussen, Eucken, von Hartmann, Riehl, Wundt, and others, we may well affirm that new light will continue to break forth from that country which so powerfully aroused the whole Western World at the end of the eighteenth and beginning of the nineteenth centuries. In Great Britain the name and works of Thomas Hill Green have influenced the attempts at a reconstruction of systematic philosophy in a manner to satisfy at one and the same time both the facts and laws of science and the æsthetical, ethical, and religious ideals of the age, in a very considerable degree. And in this attempt, both as it expresses itself in theoretical psychology and in the various branches of philosophical discipline, writers like Bradley, Fraser, Flint, Hodgson, Seth, Stout, Ward, and others, have taken a conspicuous part. Nor are there wanting in Holland, Italy, and even in Sweden and Russia, thinkers equally worthy of recognition, and recognized, in however limited and unworthy fashion, in their own land. The names of those in America who have labored most faithfully, and succeeded best, in this enormous task of reconstructing philosophy in a systematic way, and upon a basis of history and of modern science, I do not need to mention; they are known, or they surely ought to be known, to us all.

In attempting to summarize the gains of philosophy during the last hundred years, we should remind ourselves that progress in philosophy does not consist in the final settlement, and so in the "solving" of any of its great problems. Indeed, the relations of philosophy to its grounds in experience, and the nature of its method and of its ideal, are such that its progress can never be expected to put an end

to itself. But the content of the total experience of humanity has been greatly enriched during the last century; and the critical and reflective thought of trained minds has been led toward a more profound and comprehensive theory of Reality, and toward a doctrine of values that shall be more available for the improvement of man's political, social, and religious life.

In view of this truth respecting the limitations of systematic philosophy, I think we may hold that certain negative results, which are customarily adduced as unfavorable to the claims of philosophical progress, are really signs of improvement during the latter half of the nineteenth century. One is an increased spirit of reserve and caution, and an increased modesty of claims. This result is perhaps significant of riper wisdom and more trustworthy maturity. Kant believed himself to have established for philosophy a system of apodeictic conclusions, which were as completely forever to have displaced the old dogmatism as Copernicus had displaced the Ptolemaic astronomy. But the steady pressure of historical and scientific studies has made it increasingly difficult for any sane thinker to claim for any system of thinking such demonstrable validity. May we not hope that the students of the particular sciences, to whom philosophy owes so much of its enforced sanity and sane modesty, will themselves soon share freely of the philosophic spirit with regard to their own metaphysics and ethical and religious standpoints, touching the Ultimate Reality? Even when the recoil from the overweening self-satisfaction and crass complacency of the earlier part of the last century takes the form of melancholy, or of acute sadness, or even of a mild despair of philosophy, I am not sure that the last state of that man is not better than the first.

In connection with this improvement in spirit, we may also note an improvement in the method of philosophy.

The purely speculative method, with its intensely interesting but indefensible disregard of concrete facts, and of the conclusions of the particular sciences, is no longer in favor even among the most ardent devotees and advocates of the superiority of philosophy to those sciences. At the same time, philosophy may quite properly continue to maintain its position of independent critic, as well as of docile pupil, toward the particular sciences.

In the same connection must be mentioned the hopeful fact that the last two or three decades have shown a decided improvement in the relations of philosophy toward the positive sciences. There are plain signs of late that the attitude of antagonism, or of neglect, which prevailed so largely during the second and third quarters of the nineteenth century, is to be replaced by one of friendship and mutual helpfulness. And, indeed, science and philosophy cannot long or greatly flourish without reciprocal aid, if by science we mean a true *Wissenschaft* and if we also mean to base philosophy upon our total experience. For science and philosophy are really engaged upon the same task,—*to understand and to appreciate the totality of man's experience.* They, therefore, have essential and permanent relations of dependence for material, for inspiration and correction, and for other forms of helpfulness. While, then, their respective spheres have been more clearly delimited during the last century, their interdependence has been more forcefully exhibited. Both of them have been developing a systematic exposition of the universe. Both of them desire to enlarge and deepen the conception of the Being of the World, as made known to the totality of human experience, in its Unity of nature and significance. We cannot believe that the end of the nineteenth century would sustain the charge which Fontenelle made in the closing years of the seventeenth century: "*L'Académie*

des Sciences ne prend la nature que par petites parcelles." Science itself now bids us regard the Universe as a dynamical Unity, teleologically conceived, because in a process of evolution under the control of immanent ideas. Philosophy assumes the same point of view, rather at the beginning than at the end of defining its purpose; and so feels a certain glad leap at its heart-strings, and an impulse to hold out the hand to science, when it hears such an utterance as that of Poincaré: *Ce n'est pas le méchanisme le vrai, le seul but; c'est l'unité.*

Shall we not say, then, that this double-faced but wholly true lesson has been learned: namely, that the so-called philosophy of nature has no sound foundation and no safeguard against vagaries of every sort, unless it follows the lead of the positive sciences of nature; but that the sciences themselves can never afford a full satisfaction to the legitimate aspirations of human reason unless they, too, contribute to the philosophy of nature—writ large and conceived of as a real-ideal Unity.

That nature, as known and knowable by man, is a great artist, and that man's æsthetical consciousness may be trusted as having a certain ontological value, is the postulate properly derived from the considerations advanced in the latest, and in some respects the most satisfactory, of the three Critiques of Kant. The ideal way of looking at natural phenomena which so delighted the mind of Goethe has now been placed on broad and sound foundations by the fruitful industries of many workmen,—such as Karl Ernst von Baer and Charles Darwin,—whose morphological and evolutionary conceptions of the universe have transformed the current conceptions of cosmic processes. But the word of physical and natural phenomena has thereby been rendered not less, but more, of a Cosmos, an orderly totality.

In addition to these more general but somewhat vague

evaluations of the progress of philosophy during the nineteenth century, we are certainly called upon to face the question whether, after all, any advance has been made toward the more satisfactory solution of the definite problems which the Kantian criticism left unsolved. To this question I believe an affirmative answer may be given in accordance with the facts of history. It will be remembered that the first of these problems was the epistemological. Certainly no little improvement has been made in the psychology of cognition. We can no longer repeat the mistakes of Kant, either with respect to the uncritical assumptions he makes regarding the origin of knowledge in the so-called "faculties" of the human mind or regarding the analysis of those faculties and their interdependent relations. It is not the Scottish philosophy alone which has led to the conclusion that, in the word of the late Professor Adamson, "What are called acts or states of consciousness are *not* rightly conceived of as having for their objects their own modes of existence as ways in which a subject is modified." And in the larger mannor both science and philosophy, in their negations and their affirmations, and even in their points of view, have better grounds for the faith of human reason in its power progressively to master the knowledge of Reality than was the case a hundred years ago. Nor has the skepticism of the same era, whether by shallow scoffing at repeated failures, or by pious sighs over the limitations of human reason, or by critical analysis of the cognitive faculties "according to well-established principles," succeeded in limiting our speculative pretensions to the sphere of possible experience,—in the Kantian meaning both of "principles" and of "experience." But what both science and philosophy are compelled to agree upon as a common underlying principle is this: The proof of the most fundamental presuppositions, as well as of the latest more scientifically

established conclusions, of both science and philosophy, is the assistance they afford in the satisfactory explanation of the totality of racial experience.

In the evolution of the ontological problem, as compared with the form in which it was left by the critical philosophy, the past century has also made some notable advances. To deny this would be to discredit the development of human knowledge so far as to say that we know no more about what nature is, and man is, than was known a hundred years ago. To say this, however, would not be to speak truth of fact. And here we may not unnaturally grow somewhat impatient with that metaphysical fallacy which places an impassable gulf between Reality and Experience. No reality is, of course, cognizable or believable by man which does not somehow show its presence in his total experience. But no growth of experience is possible without involving increase of knowledge representing Reality. For Reality is no absent and dead, or statical, Ding-an-Sich. Cognition itself is a commerce of realities. And are there not plain signs that the more thoughtful men of science are becoming less averse to the recognition of the truth of ontological philosophy; namely, that the deeper meaning of their own studies is grasped only when they recognize that they are ever face to face with what they call Energy and we call Will, and with what they call laws and we call Mind as significant of the progressive realization of immanent ideas. This Ultimate Reality is so profound that neither science nor philosophy will ever sound all its depths, and so comprehensive as more than to justify all the categories of both.

Probably, on the whole, there has been less progress made toward a satisfactory solution of the problems offered by the value-judgments of ethics and religion, in the form in which these problems were left by the critical philosophy.

The century has illustrated the truth of Falckenberg's statement: "In periods which have given birth to a skeptical philosophy, one never looks in vain for the complementary phenomenon of mysticism." Twice during the century the so-called "faith-philosophy," or philosophy of feeling, has been borne to the front, to raise a bulwark against the advancing hosts of agnostics—occasioned in the first period by the negations of the Kantian criticism, and in the second by the positive conclusions of the physical and biological sciences. This form of protesting against the neglect or disparagement of important factors which belong to man's æsthetical, ethical, and religious experience, is reasonable and must be heard. But the extravagances with which these neglected factors have been posited and appraised, to the neglect of the more definitively scientific and strictly logical, is to be deplored. The great work before the philosophy of the present age is the reconciliation of the historical and scientific conceptions of the Universe with the legitimate sentiments and ideals of art, morality, and religion. But surely neither rationalism nor "faith-philosophy" is justified in pouring out the living child with the muddy water of the bath.

IV. The attempt to survey the present situation of philosophy, and to predict its immediate future, is embarrassed by the fact that we are all immersed in it, are a part of its spirit and present form. But if nearness has its embarrassments, it has also its benefits. Those who are amidst the tides of life may know better, in a way, how these tides are tending and what is their present strength, than do those who survey them from distant, cool, and exalted heights. *"Für jeden einzelnen bildet der Vater und der Sohn eine greifbare Kette von Lebensereignungen und Erfahrungen."* The very intensely vital and formative but unformed condition of systematic philosophy—its proto-

plasmic character—contains promises of a new life. If we may believe the view of Hegel that the systematizing of the thought of any age marks the time when the peculiar living thought of that age is passing into a period of decay, we may certainly claim for our present age the prospect of a prolonged vitality.

The nineteenth century has left us with a vast widening of the horizon,—outward into space, backward in time, inward toward the secrets of life, and downward into the depths of Reality. With this there has been an increase in the profundity of the conviction of the spiritual unity of the race. In the consideration of all of its problems in the immediate future and in the coming century—so far as we can see forward into this century—philosophy will have to reckon with certain marked characteristics of the human spirit which form at the same time inspiring stimuli and limiting conditions of its endeavors and achievements. Chief among these are the greater and more firmly established principles of the positive sciences, and the prevalence of the historical spirit and method in the investigation of all manner of problems. These influences have given shape to the conception which, although it is as yet by no means in its final or even in thoroughly self-consistent form, is destined powerfully to affect our philosophical as well as our scientific theories. This conception is that of Development. But philosophy, considered as the product of critical and reflective thinking over the more ultimate problems of nature and of human life, is itself a development. And it is now, more than ever before, a development interdependently connected with all the other great developments.

Philosophy, in order to adapt itself to the spirit of the age, must welcome and cultivate the freest critical inquiry into its own methods and results, and must cheerfully submit itself to the demand for evidences which has its roots

in the common and essential experience of the race. Moreover, the growth of the spirit of democracy, which, on the one hand, is distinctly unfavorable to any system of philosophy whose tenets and formulas seem to have only an academic validity or a merely esoteric value, and which, on the other hand, requires for its satisfaction a more tenable, helpful, and universally applicable theory of life and reality, cannot fail, in my judgment, to influence favorably the development of philosophy. In the union of the speculative and the practical; in the harmonizing of the interests of the positive sciences, with their judgments of fact and law, and the interests of art, morality, and religion, with their value-judgments and ideals; in the synthesis of the truths of Realism and Idealism, as they have existed hitherto and now exist in separateness or antagonism; in a union that is not accomplished by a shallow eclecticism, but by a sincere attempt to base philosophy upon the totality of human experience;—in such a union as this must we look for the real progress of philosophy in the coming century.

Just now there seem to be two somewhat heterogeneous and not altogether well-defined tendencies toward the reconstruction of systematic philosophy, both of which are powerful and represent real truths conquered by ages of intellectual industry and conflict. These two, however, need to be internally harmonized, in order to obtain a satisfactory statement of the development of the last century. They may be called the evolutionary and the idealistic. The one tendency lays emphasis on mechanism, the other on spirit. Yet it is most interesting to notice how many of the early workmen in the investigation of the principle of the conservation and correlation of energy took their point of departure from distinctly theological and spiritual conceptions. "I was led," said Colding,—to take an extreme case,

—at the Natural Science Congress at Innsbruck, 1869, "to the idea of the constancy of national forces by the religious conception of life." And even Moleschott, in his *Autobiography,* posthumously published, declares: "I myself was well aware that the whole conception might be converted; for since all matter is a bearer of force, endowed with force or penetrated with spirit, it would be just as correct to call it a spiritualistic conception." On the other hand, the modern, better instructed Idealism is much inclined, both from the psychological and from the more purely philosophical points of view, to regard with duly profound respect all the facts and laws of that mechanism of Reality, which certainly is not merely the dependent construction of the human mind functioning according to a constitution that excludes it from Reality, but is rather the ever increasingly more trustworthy revealer of Reality. This tendency to a union of the claims of both Realism and Idealism is profoundly influencing the solution of each one of these problems which the Kantian criticism left to the philosophy of the nineteenth century. In respect of the epistemological problem, philosophy—as I have already said—is not likely again to repeat the mistakes either of Kant or of the dogmatism which his criticism so effectually overthrew. It was a wise remark of the physician Johann Benjamin Erhard, in a letter dated May 19, 1794, *à propos* of Fichte: "The philosophy which *proceeds* from a *single* fundamental principle, and pretends to deduce everything from it, is and always will remain a piece of artificial sophistry: only that philosophy which *ascends* to the highest principle and exhibits everything else in perfect harmony with it, is the true one." This at least ought—one would say—to have been made clear by the century of discussion over the epistemological problem, since Kant. You cannot *deduce* the Idea from the Reality, or the Reality from the Idea.

The problem of knowledge is not, as Fichte held in the form of a fundamental assumption, an alternative of this sort. The Idea *and* Reality are, the rather already there, and to be recognized as in a living unity, in every cognitive experience. Psychology is constantly adding something toward the problem of cognition as a problem in synthesis; and is then in a way contributing to the better scientific understanding of the philosophical postulate which is the confidence of human reason in its ability, by the harmonious use of all its powers, progressively to reach a better and fuller knowledge of Reality.

The ontological problem will necessarily always remain the unsolved, in the sense of the very incompletely solved problem of philosophy. But as long as human experience develops, and as long as philosophy bestows upon the experience the earnest and candid efforts of reflecting minds, the solution of the ontological problem will be approached, but never fully reached. That Being of the World which Kant, in the negative and critical part of his work, left as an *X*, unknown and unknowable, the last century has filled with a new and far richer content than it ever had before. Especially has this century changed the conception of the Unity of the Universe in such manner that it can never return again to its ancient form. On the one hand, this Unity cannot be made comprehensible in terms of any one scientific or philosophical principle or law. Science and philosophy are both moving farther and farther away from the hope of comprehending the variety and infinite manifoldness of the Absolute in terms of any one side or aspect of man's complex experience. But, on the other hand, the confidence in this essential Unity is not diminished, but is the rather confirmed. As humanity itself develops, as the Selfhood of man grows in the experience of the world which is its own environment, and of the world within which

it is its own true Self, humanity may reasonably hope to win an increased, and increasingly valid, cognition of the Being of the World as the Absolute Self.

Closely connected, and in a way essentially identical with the ontological problem, is that of the origin, validity, and rational value of the ideas of humanity. May it not be said that the nineteenth century transfers to the twentieth an increased interest in and a heightened appreciation of the so-called practical problems of philosophy. Science and philosophy certainly ought to combine—and are they not ready to combine?—in the effort to secure a more nearly satisfactory understanding and solution of the problems afforded by the æsthetical, ethical, and religious sentiments and ideals of the race. To philosophy this combination means that it shall be more fruitful than ever before in promoting the uplift and betterment of mankind. The fulfillment of the practical mission of philosophy involves the application of its conceptions and principles to education, politics, morals, as a matter of law and of custom, and to religion as matter both of rational faith and of the conduct of life.

How, then, can this brief and imperfect sketch of the outline of the development of philosophy in the nineteenth century better come to a close than by words of encouragement and of exhortation as well. There are, in my judgment, the plainest signs that the somewhat too destructive and even nihilistic tendencies of the second and third quarters of the nineteenth century have reached their limit; that the strife of science and philosophy, and of both with religion, is lessening, and is being rapidly displaced by the spirit of mutual fairness and reciprocal helpfulness; and that reasonable hopes of a new and a splendid era of reconstruction in philosophy may be entertained. For I cannot agree with the *dictum* of a recent writer on the sub-

ject, that "the sciences are coming less and less to admit of a synthesis, and not at all of a synthetic philosopher."

On the contrary, I hold that, with an increased confidence in the capacity of human reason to discover and validate the most secret and profound, as well as the most comprehensive, of truths, philosophy may well put aside some of its shyness and hesitancy, and may resume more of that audacity of imagination, sustained by ontological convictions, which characterized its work during the first half of the nineteenth century. And if the latter half of the twentieth century does for the constructions of the first half of the same century, what the latter half of the nineteenth century did for the first half of that century, this new criticism will only be to illustrate the way in which the human spirit makes every form of its progress.

Therefore, a summons of all helpers, in critical but fraternal spirit, to this work of reconstruction, for which two generations of enormous advance in the positive sciences has gathered new material, and from the better accomplishment of which both the successes and the failures of the philosophy of the nineteenth century have prepared the men of the twentieth century, is the winsome and imperative voice of the hour.

THE RELATIONS OF PALEONTOLOGY TO OTHER BRANCHES OF SCIENCE.

BY ARTHUR SMITH WOODWARD

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THE satisfactory interpretation of fossils depends on knowledge of so many kinds that it is not surprising the study of them was scientifically pursued for nearly half a century before it received a distinctive name. Even after paleontology had been added to the roll of the sciences, the universities still regarded it as a department of geology, zoölogy, or comparative anatomy. In fact, to this day there is no separate ordinary chair of paleontology in any of the European universities, and there are very few chairs devoted to this science even in the more progressive universities of America. It is the general custom for the professor of geology to treat the invertebrate fossils, with special reference to their use in determining the age of rocks; while the professor of zoölogy or comparative anatomy usually includes the vertebrate fossils in his course, to supply some of the many links which are missing in the surviving chain of life. Under such circumstances, there is no difficulty in recognizing that paleontology is intimately

related to other geological and biological sciences. The obstacle to a correct appreciation of the subject is rather that the divided teaching fails to impart to the student any adequate idea of its fundamental broad principles and their true meaning.

Relations to Geology

It is quite natural that paleontology should still be regarded as a subsidiary part of geology, for it developed from the study of the so-called "figured stones" and "mineral conchology," which were so much discussed more than a century ago. It is based entirely upon fossils, which lose much of their real value unless they are carefully collected by a geologist; and the fossils themselves can only be properly understood by one whose eye is accustomed to the examination of rocks and mineral structures. Moreover, it has been quite clear since the days of William Smith, Cuvier, and Brongniart that fossils always occur in a definite order in the rocks of different ages, so that they afford a means of correlating the formations of widely separated localities whose mutual relationships are otherwise uncertain. To use Mantell's well-known phrase, they are therefore "medals of creation," and an intimate knowledge of them is absolutely essential to a geologist when he attempts to determine the relative age of sedimentary deposits which he cannot directly observe in superposition.

The researches of paleontologists during the last two decades, however, have considerably amplified the original conception of fossils as an index to geological time. So long as detailed observations were mainly confined to one small portion of the earth's surface, it was possible to enumerate a few characteristic genera for each stratum of rock; and when geological discoveries began to be made in distant countries, it was found that the general succession of

fossil groups of animals was always the same—that graptolites and trilobites, for example, were invariably older than ammonites, and that these again always preceded the volutes. At the present day a skilled paleontologist can determine the age of a fauna with much greater precision. The broad outlines of the evolution of most groups of animals have now been ascertained; and when a new set of fossils is discovered in a hitherto unknown formation, the paleontologist does not occupy himself so much with the search for familiar genera as with an inquiry into the stage of evolution of the various groups represented.

This has been pointed out by many authors, but none have stated the case more clearly than Gaudry, who has devoted special attention to the mammalia.[1] The warm-blooded quadrupeds or mammals began as little small-brained animals, each with a continuous series of bluntly-cusped teeth round the edge of the mouth, with flattened vertebræ, and with five toes on each foot. A group of fossil remains representing only such animals would be referred to the Eocene Tertiary; and if some of the species had grown to bulky proportions and developed horns, the fauna might be described without hesitation as Middle or Upper Eocene. Groups of mammals progressively differing from this original race in (1) the larger size of the brain, (2) special adaptation of the teeth to flesh-tearing or vegetable-grinding, (3) greater mobility of the neck, and (4) adaptation of the feet either to grasping prey or to running on hard ground, mark successive geological periods. The general succession is always the same whatever may be the local circumstances; and for this reason it is impossible to accept the published conclusions of the brothers Ameghino as to the age of the various mammal-bearing Tertiary deposits of Patagonia. The mammals of South

[1] A. Gaudry, *Essai de Paléontologie Philosophique* (1896), pp. 178-197.

America are certainly anomalous, but the marine fossils intercalated between some of the deposits containing bones in Patagonia prove that the rate of mammalian evolution was much the same there as in other lands. Even Australia, which is in many respects a remnant of the Mesozoic world, can be readily recognized by its mammals as modern Tertiary. The monotremes are certainly a very ancient type, but their large brains, peculiar skulls, and rudimentary or lost teeth show that they belong to a far later period than that at which their lowly tribe flourished. Similarly the kangaroos have highly specialized teeth and feet which cannot be misinterpreted.

Relations to Cosmical Physics

While fossils prove that the succession of life during geological time has been essentially the same everywhere, it is still impossible to determine exactly which faunas were contemporaneous in different parts of the world. A deposit containing Carboniferous fossils, for example, in Australia was not necessarily formed at precisely the same time as a rock yielding similar fossils in the Arctic regions. There may have been migration, and the Carboniferous animals and plants may have quitted the Australian region long before they reached the Arctic Circle, or *vice versa*. To obviate the use of the word "contemporaneous" in referring to such a case, Huxley long ago proposed the more indefinite adjective "homotaxial," which postulates nothing more than the identity of two rocks in their fossil contents; and there is at present no prospect of dispensing with this provisional term. It is therefore unfortunate, but true, that paleontology gives only very uncertain information about the distribution of heat over the surface of the globe in past ages. It is perfectly clear from fossils that climates have changed in nearly all if not all parts of the

AN ARMORED DINOSAUR

Some of the most remarkable prehistoric animals, whose bones have been recovered from the drifts and deposits of many centuries, now belong to the natural history department of the Smithsonian Institution in Washington. These restorations are generally of plaster, however, the bones found being too few to permit articulation of a perfect skeleton. Among the most curious is an armored dinosaur, a huge reptilian creature that once roamed the plains of what are now Wyoming, Colorado and Kansas, distinguished among others of its species by a small head, large projecting plates on the back, and stout spines on the tail. Its extreme length is about thirty feet.

world; it is not equally evident how these changes of climate in different regions were related to each other.

Fossils, however, can only be used as tests of climate with special caution. When, by analogy with the existing world of life, a whole fauna agrees with the associated whole flora in indicating certain climatic conditions, the mean temperature under which it flourished is doubtless approximately determinable. When the evidence is less nearly complete, it can hardly be satisfactory. To appreciate this, it is only necessary to remember that a fossil elephant, a rhinoceros, and a tiger have been found in undoubted glacial deposits in the arctic regions; while the hippopotamus is represented by abundant remains in the Pleistocene river-gravels of England, which were deposited under a by no means warm clime. Even in the case of plants, there is the oft-quoted occurrence of palms at the present day in the neighborhood of glaciers in New Zealand.

Allowing for such difficulties and uncertainties, the general inference to be deduced from all the available evidence of fossils is, perhaps, that until the end of the Mesozoic period the difference of mean temperature between the various latitudes was much less than it is at present. Paleontology suggests, indeed, that the polar ice-caps were comparatively insignificant until the latter half of the Tertiary period. Fossils of many ages, indicating at least a temperate climate, have long been known within the Arctic Circle;[1] and similar discoveries have just begun in the ice-bound Antarctic regions. The Swedish Antarctic expedition has brought back from Louis-Philippe Land in S. lat. 63° 15′ a series of Jurassic ferns, cycads, and conifers, which, according to Professor Nathorst,[2] might have been

[1] J. W. Gregory, *Some Problems of Arctic Geology, Nature,* vol. 56 (1897), pp. 301-303, 351, 352.

[2] A. G. Nathorst, *Sur la Flore fossile des Régions antarctiques, Comptes Rendus,* vol. 138, pp. 1447-1450 (June 6, 1904).

collected in the Inferior Oolite of the Yorkshire coast. The same expedition has also obtained remains of ferns, conifers, and dicotyledons from a Tertiary formation in S. lat. 64° 15′. In this case, however, the fossils were found in a marine deposit and may possibly have been drifted for a long distance. As remarked by Professor Nathorst,[1] "The dredgings of Dr. Agassiz have proved that a mass of leaves, wood, and fruits may occur at the bottom of the sea even at a distance of more than 1000 kilometers from the nearest land." Hence it must be left for future discoveries to decide whether or not the Tertiary Antarctic plants actually grew in the latitude where they were found.

While thus of some value in indicating ordinary climatal changes, fossils do not date back far enough to be considered in relation to any of the fundamental problems of cosmogony. It has been ingeniously argued[2] that life must have originated at the poles because those regions cooled first; and some authors have maintained that even during the Tertiary period fossils prove the land within the Arctic Circle to have been the main centre from which successive new types of life arose and dispersed. The oldest known fossils, however, occur in rocks at the base of the Cambrian series, both in the tropics and in the far north; and there is as yet no means of determining whether the animals represented by these fossils spread from the north, south, or equatorial regions, or from several points. There is thus no direct evidence from fossils for or against the theory of the polar origin of life. The facts supposed to show that the same area continued to be a source of new organisms even until the later Tertiary period admit of other interpretations which are in better accord with the newest discoveries.

[1] *Loc. cit.* p. 1450.

[2] G. Hilton Scribner, *Where did Life Begin?* (ed. 2, New York, 1903).

Even of changes which may have occurred since the globe became habitable, fossils furnish no reliable indications. Professor G. H. Darwin's theory of the former magnitude of the tides is as completely unsupported by paleontology as by geology. The idea that the earth's atmosphere has gradually altered in constitution since life began is equally destitute of support from fossils. The microscopical structure of the leaves of the Carboniferous plants suggests that even at so remote a period as that when they flourished, the air was essentially identical with that of the present day, without any superfluity of carbon dioxide or anything to obstruct the full influence of the sun's rays.[1]

Relations to Geography

So far as can be judged at present, paleontology justifies the assumption that each type of animal or plant has only originated once and from one set of ancestors. Fossils can therefore be used as an aid to the solution of geographical problems. If a more or less sedentary group of animals is found to be essentially identical in two widely separated seas, it may be reasonably assumed either that those seas were once connected, or that they received their life from a common source. Similarly, if two distant tracts of land are inhabited by the same animals and plants, and there is no possibility at present of migration between these two regions, a former connection either with each other or with a common centre may also be postulated. The same is true in reference to all periods of the earth's history, and hence the varying distribution of fossils at different epochs affords a clue to the successive changes in the disposition of lands and seas, gradually culminating in their present arrangement.

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[1] A. C. Seward, *Fossil Plants as Tests of Climate* (*Sedgewick Prize Essay*, 1892), pp. 71-76.

For instance, it has been lately noticed[1] that the mollusca living on the two opposite coasts of the North Pacific during the Pliocene period were much more nearly identical than they are at the present day. In other words, the coast-line seems to have been continuous at that time, a neck of land uniting Asia and North America where now there exists the Bering Strait. The Pliocene land-animals of the northern hemisphere agree in suggesting the same connection. Hence, the ultimate separation of the so-called Old and New Worlds is shown by fossils to be quite a modern event in geological history.

Again, it has been proved by recent researches[2] that the mollusks, brachiopods, and trilobites found in the Devonian rocks of South Africa, agree much more closely with those occurring in the corresponding formations of South and North America than with those of Europe. The South African sea in the Devonian period seems therefore to have extended directly into the American region, but to have been separated by a barrier from the European region. Similarly, there is evidence of circumscribed seas separated by land-barriers in the Triassic, Jurassic, and other epochs; and when the fossils from all parts are sufficiently well known, it will be possible to determine even some of the minor geographical features of each successive period.

To restore the old continents and to discover their varying connections and disintegrations is an especially fascinating problem. A means of solution is provided by the various terrestrial vertebrates, which, under ordinary circumstances, are unable to cross seas. When a new race suddenly appears in any land, it obviously implies the removal of the barrier which previously prevented that race

[1] R. Arnold, *The Paleontology and Stratigraphy of the Marine Pliocene and Pleistocene of San Pedro, California*. Memoirs of the Calif. Acad. Sci., vol. III (1903).

[2] F. R. C. Reed and P. Lake, *Ann. S. African Museum*, vol. iv, pts. 3, 4, 6 (1903-04).

from spreading. The primitive elephants, for example, suddenly invaded Europe at the beginning of the Miocene period. Recent discoveries in the Egyptian desert have proved that their ancestors lived and evolved in the Eocene and Oligocene periods in northern Africa.[1] Therefore, during this earlier time, the European and African regions were separated by some barrier, doubtless the sea; at the dawn of the Miocene period earth-movements of some kind resulted in a land connection over which mammals could migrate.

The use of terrestrial vertebrates in deciphering the past history of continents is, however, less simple than it may at first sight appear; and the case of South Africa may be quoted as an interesting illustration. With reference to the latest phases in the development of this land, only two main conclusions are well founded. The first fact to notice is that, of the jaguars, pumas, wolves, bears, tapirs, deer and llamas, which characterize South America, and of the mastodons and horses which lived there in the Pleistocence period, there are no remains in the geological formations of that country below the top of the Pliocene. Hence, as representatives of all these quadrupeds lived at an earlier date in North America, there must have been some barrier, evidently a sea, which separated the northern and southern parts of America during the greater part of the Tertiary epoch, and only disappeared to allow the free migration of land animals towards the close of the Pliocene period. The removal of this barrier, which is also indicated by purely geological researches, resulted thus in a mingling of the native South American Tertiary fauna with a host of invaders, whose ancestors flourished on the lands of the northern hemisphere. In other words, the surviving land

[1] C. W. Andrews, "On the Evolution of the Proboscidea," *Phil. Trans.* 1903, on B. 217.

animals of South America have been derived from two sources—some from the native stock which evolved in the country itself during the Tertiary epoch, some from the late Pliocene invasion of northern life. Now, the native stock just mentioned is of uncertain origin, but in its prime it included the New World monkeys, many peculiar rodents, the sloths, anteaters, and armadillos, and numerous remarkable hoofed animals—altogether an assemblage unknown in any other region of the world. Therefore, it seems impossible to escape from the further conclusion that during the greater part of the early Tertiary epoch South America was an isolated land, and its mammals developed independently of those of other continents. On the other hand, it is to be observed that during part of this time there lived in South America several primitive carnivorous animals, perhaps marsupials, which were most strikingly similar to the thylacines and dasyures of the Australian region. There was also a horned land-tortoise, *Miolania,* essentially identical with one of which species occur in the Pleistocene deposits of Australia and Lord Howe's Island. Finally, there was the familiar mud-fish, *Ceratodus,* which now survives only in the Queensland rivers. It has therefore been thought that the occurrence of remains of these animals among the Tertiary fossils of South America favors the theory of a former land connection between that country and Australia. In fact, they are sometimes quoted as helping to confirm the hypothesis of the former existence of a great Antarctic continent, which has broken up into the lands now known as Australia, New Zealand, South Africa, and South America. The surviving thylacines of the Australian region, however, are the very slightly altered descendants of a race of small-brained, primitive carnivores, which are known to have lived throughout the northern hemisphere, and were probably cosmopolitan at the begin-

ning of the Tertiary epoch. The Middle Tertiary carnivores of South America and the modern thylacines of Australia may, therefore, be merely the last survivors of an effete race, which was exterminated early at all points except the two extremes of its once extensive range. Similarly, *Miolania* is a horned and armored member of a suborder of tortoise (Pleurodira), which was probably almost as nearly cosmopolitan at the end of the Mesozoic and beginning of the Tertiary epoch as is the suborder of Cryptodiran tortoises in the existing world. *Ceratodus* was also universally disturbed in the waters, probably even in the seas, of the middle part of the Mesozoic epoch. So that in each of these three cases Australia and South America may be merely refuges for old forms of life which were lost much earlier by extinction in other parts of the world. They need not have been directly connected.

In short, when using land animals or fresh-water animals as tests of former changes in the distribution and connection of land areas, it is necessary to make a distinction between those of restricted range and those of past or present cosmopolitan distribution, the former alone affording reliable evidence.

Relations to Biology

It is already clear that the scientific value of a fossil depends upon the exactness with which the circumstances of its discovery are determined by a geologist. The briefest experience is also enough to demonstrate that the well-mineralized remains of an organism can only be satisfactorily interpreted by an observer who is familiar with the structure of rocks and their common constituents. The student of fossils needs as much elementary training in the geological succession of the rocks and the varied nature of mineralization as the student of histology and embryology

requires to locate his sections with exactitude, and to understand the action of the different stains and media he employs. In the one case nature makes the preparation; in the other case the processes of laboratory technique are responsible for the difficulties. In both cases, there is hope for numerous fantastic conclusions if the properties of the preservative medium are misunderstood.

Paleontology, however, is essentially a department of biology, and it can only be prosecuted with success by a skilled biologist, who has had the elementary geological and mineralogical experience just mentioned. It bears, indeed, the same relation to the whole world of life that embryology bears to the structure of an individual organism. The one deals with the rise and growth of races and their varying relationship; the other describes and interprets the evolution of an individual and the processes by which the different parts of its mechanism are finally adjusted. Both unfortunately depend on extremely imperfect material; for fossils are nearly always mere badly preserved skeletons, and they represent only an infinitesimal fraction of the life that has passed away, while embryos are so much adapted to the peculiar circumstances of their environment that many of the essential stages in their growth and development are obscured and modified by temporary expedients.

The past history of the world of life, as revealed by fossils, has long been familiar in its general outlines. At least a century has elapsed since it was made clear that the various organisms come into existence at different times and in a definite order, according to their grade in the scale of being, the lowest first, the highest latest. Several decades have also passed away since it was recognized that within each group the lowest or most generalized members appeared earliest, the highest, most specialized, or most degenerate towards the end of the race. Modern research is

concerned only with the details of this succession, and with the laws which can now be deduced from the rapidly multiplying available facts.

Our present knowledge of the geological succession of the fishes may be briefly summarized to show how paleontology contributes to the solution of the fundamental problems of biology. The earliest recognizable fish-like organisms, which occur in Upper Silurian formations, seem to have been mere grovelers in the mud of shallow seas, nearly all with incompletely formed jaws and no paired fins, devoting most of their growth-energy to the production of an effective armor by the fusion of dermal tubercles into plates (*Ostracodermi*). With them were a few true fishes which had completed jaws, but which possessed a pair of lateral fin-folds, variously subdivided, instead of the ordinary two pairs of fins (*Diplacanth Acanthodii*). The main features of Silurian fish-life were, therefore, the acquisition of dermal armor, definite jaws, and the beginning of paired fins. Some of the lowly types thus equipped survived and further evolved in the Devonian period; but the multitude of new-comers which then formed the majority were much higher in the scale of being (*Crossopterygii*). They were still adapted for the most part to live on the bottom of shallow water or in marshes, but they were typical well-formed fishes in respect to their jaws, branchial apparatus, and two pairs of fins. Nearly all their bones were external, very little of their internal skeleton being ossified; and the only changes they seem to have been undergoing related to the fusion of some of the head-bones and the more exact adaptation of their fins and tail to their environment. Fishes more fitted for sustained swimming were also beginning to appear, and these (*Palæoniscidæ*) formed the large majority in the succeeding Carboniferous and Permian periods. They were about equivalent in grade to the mod-

ern sturgeons, and the tendency towards change in their structure was in the direction of effective swimming, by the more intimate correlation between the fin-rays and their supports, and by the shortening of the upper lobe of the tail. They still exhibited scarcely any ossification of the internal skeleton. As soon as the best type of balancing-fin and the most effective type of propelling tail-fin had become universal among the highest fish-life of the Triassic period, the internal skeleton began to ossify and vertebral centra arose. In fact, the whole of the succeeding Jurassic period was spent by the highest fishes in improving and finishing their internal skeleton, while their external bony armor began almost universally to degenerate. Thus, by the early part of the Cretaceous period the most advanced members of the class had already become true bony fishes or *Teleosteans*. Having attained that stage of complexity they admitted of much more variation than formerly, and then arose the immense host of fishes which characterize the Tertiary period and the present day. For the first time in fish-history, there were fundamental changes in the head. First, in some genera the maxilla began to slip behind and above the premaxilla, so that it was excluded from the gape. Next, in these and most other fishes, the ear-capsules began to enlarge to such an extent that the original roof of the brain-case eventually formed only an insignificant part of the top of the skull. At the same time the lateral muscles of the trunk extended forward over the cranial roof, and various crests arose between them. Finally, it was quite common for the pelvic fins to be displaced forward beneath the pectoral fins while the vertebræ, as well as some of the fin-rays, were usually reduced to a definite and fixed number for each family or genus. Simultaneously, many of the fin-rays were modified into spines, and there was a constant tendency for the external bones and scales to become

spinose. At all stages of this progress there were, of course, stragglers left by the way; and the modern fish-fauna is, therefore, a mixture of slightly modified survivors of many periods in the earth's history.

To state this brief summary in more general terms, fossils prove that the earliest known fish-like organisms strengthened their external armor so long as they remained comparatively sedentary; that next the most progressive members of the class began to acquire better powers of locomotion, and concentrated all their growth-energy on the elaboration of fins; that, after the perfection of these organs, the internal bony skeleton was completed at the sacrifice of outer plates, because rapid movement necessitated a flexible body and rendered external armor less useful; that finally, in the highest types, the vertebræ and some of the fin-rays were reduced to a fixed and practically invariable number for each family or genus, while there was a remarkable development of spines. As survivors of most of these stages still exist, the changes in the soft parts which accompanied the successive advances in the skeleton can be inferred. Hence, paleontology furnishes a sure basis for a natural classification in complete accord with the development of the group.

Now, fishes are acquatic animals and nearly all the fossiliferous rocks were deposited in water. The past history of this chain of life ought therefore to be almost completely revealed by the geological records. Making due alowance for the imperfection of collections and the accidental nature of the discovery of fossils, the general outlines of this history may indeed be considered as tolerably well ascertained. Thus the facts of paleontology not only aid the biologist in discovering the true relationships of the fishes; at the same time they afford a definite means of determining with certainty some of the fundamental principles of organic

evolution illustrated by them. As identical principles may be deduced from other departments of paleontology, most of them are not likely to be altered in any essential respects by future discoveries.

It must suffice here to allude only to a few of these general results which seem to be of far-reaching importance, omitting details which may be obtained from special treatises. Foremost among them is the demonstration that the evolution of the animal world has not proceeded uniformly but in a rhythmic manner. As soon as fishes had acquired the paddle-shaped paired fins, they suddenly became the special feature of the Devonian period in all parts of the globe that have hitherto been geologically examined, and they attained their maximum development, being more numerous and more diverse in form than at any subsequent time. None of these paddle-finned fishes (*Crossopterygii*) in the course of their varied development made much approach towards passing into the next grade of fish-life with short-based paired fins and a heterocercal tail (*Chondrostei*); but among their earliest representatives there was at least one member of the higher group, which suggests that the latter arose when the previous group was just becoming vigorous. At the beginning of the Carboniferous period the higher grade of fish-life just mentioned suddenly became the dominant feature, and during the Carboniferous and Permian it attained its maximum development. Towards the close of the Permian period the next higher group was heralded by only one representative, but as soon as it arose in the Trias it resembled its predecessors in becoming immediately dominant, surpassing all contemporary races of fishes both in the number of individuals and in the variety of genera and species. In the Cretaceous period the highest bony fishes appeared, and at the end of that period, with the dawn of the Tertiary, they suddenly diverged into

nearly all the subdivisions which characterize the existing fish-fauna, accomplishing much more evolution in a brief interval than has taken place during the whole of the succeeding Tertiary time. In short, the fundamental advances in the grade of fish-life have always been sudden and begun with excessive vigor at the end of a long period of apparent stagnation; while each advance has been marked by the fixed and definite acquisition of some new character—an "expression point," as Cope termed it—which seems to have rendered possible, or at least been an essential accompaniment of, a fresh outburst of developmental energy. As we have seen, the successive "expression points" among fishes were the acquisition of (1) paddle-like paired fins, (2) shortened fin-bases but persistent heterocercal tail, (3) completed balancing-fins and homocercal tail, and (4) completed internal skeleton.

When fossils are examined more closely, it is interesting to observe that the geological record is most incomplete exactly at these critical points in the history of each race. There are abundant remains of the families and genera which are definitely referable to one or other order or suborder; but with them there are scarcely any of the links between these major divisions which might have been expected to occur. It must also be confessed that repeated discoveries have now left faint hope that exact and gradual links will ever be forthcoming between most of the families and genera. The "imperfection of the record," of course, may still render some of the negative evidence untrustworthy; but even approximate links would be much commoner in collections than they actually are, if the doctrine of gradual evolution were correct. Paleontology, indeed, is clearly in favor of the theory of discontinuous mutation, or advance by sudden changes, which has lately received so much support from the botanical experiments of H. de Vries.

Further results obtained from the study of fossils have a bearing even on the deepest problems of biology, namely, those connected with the nature of life itself. For instance, it is allowable to infer, from the statements already made, that the main factor in the evolution of organisms is some inherent impulse—the "bathmic force" of Cope—which acts with unerring certainty, whatever be the conditions of the moment. So far as human judgment can decide, the varied assemblage of fishes at each stage of the earth's history was always in perfect accord with its environment, and displayed very few signs of waning, even at the time when a new race suddenly took its place and provided every kind of fish once more on a higher plane or, so to speak, in a later fashion. The change was inevitable and according to some fundamental law of life whose influence is independent of temporary equilibrium. Equally inevitable and irreversible are the essential changes which may be observed during the evolution of each family of organisms. As the late Professor Beecher pointed out,[1] all animals with skeletons tend to produce a superfluity of dead matter which accumulates in the form of spines as soon as the race to which they belong has passed its prime and begins to be on the down grade; all vertebrates tend to lose their teeth when they reach the culmination of their life-history; nearly all groups of fishes end their career with eel-shaped representatives; and when a structural character has been definitely lost in the course of evolution it never reappears, but, if actually wanted again, is reproduced in a secondary makeshift. Finally, and perhaps most important of all, there is in the course of evolution of all groups of animals to their prime a tendency towards fixity in the number and regularity (or symmetry) in arrangement of their multiple parts.

[1] C. E. Beecher, *The Origin and Significance of Spines*. *Amer. Journ. Sci.* [4] Vol. VI (1898), July to October.

The assumption of a fixed number of vertebræ and fin-rays in the latest and highest families and genera of bony fishes has already been mentioned. An irregular cluster of grinding teeth characterized the Pycnodont fishes of the Lower Lias, while these teeth began to be disposed in definite regular rows in some of the Bathonian forms, and such a symmetrical arrangement henceforth pervaded the highest members of the family. Many of the lower vertebrates, both living and extinct, have teeth with multiplied cusps, and in some genera the number of teeth seems to be constant; but in the history of the vertebrates the tooth-cusps never became fixed individual entities, strictly homologous in whole races, until the highest or mammalian grade had been attained. Moreover, it is only in the same latest phase that the teeth themselves can be treated as definite units, always the same in number (44), except where modified by degeneration or special adaptation. The number of vertebræ in the neck of the lower vertebrates depends on the extent of this part, whereas in the mammal it is almost invariably seven, whatever the total length may be. Equally constant in the artiodactyl ungulate mammalia is the number of nineteen vertebræ between the neck and the sacrum.

In short, the biologist equipped with an adequate knowledge of paleontology cannot fail to perceive that throughout the evolution of the organic world there has been a periodical succession of impulses, each introducing not only a higher grade of life but also fixing some essential characters that had been variable in the grade immediately below. He must also realize that in the interval between these impulses some minor characters in the families similarly acquired fixity in their prime, until old age and extinction approached. The general conclusion is, that if the unknown influence which Cope has termed "bathmic force" were able to act without a succession of checks from the

environment and Natural Selection, animals would form much more symmetrical groups than we actually find, and their ultimate grades would display still more instances of numerical fixity in multiple parts than can be observed under existing circumstances.

This result almost tempts a paleontologist to risk the pitfalls of reasoning from analogy, and to compare organic evolution with some purely physical processes. It has already been pointed out more than once that the initial stages of animal races resemble the nascent states of chemical elements in their particular intensity of vigor and unwonted susceptibility to influence; while Cope himself has hinted that the "expression points" in the evolution of races may perhaps be compared with the phenomena of latent heat in the organic world. It now seems reasonable to add that each "phylum," or separate chain of life, bears a striking resemblance to a crystal of some inorganic substance, which has been disturbed by impurities during its growth, and has thus been fashioned with unequal faces or even turned partly into a mere concretion. In the case of a crystal, the inherent forces set solely upon molecules of the crystalline substance itself, collecting them and striving even in a disturbing environment to arrange them in a fixed geometrical shape. In the case of an organic phylum, the inherent forces of the colloid germ-plasm act upon a consecutive series of temporary outgrowths or excrescences of colloid substance (the successive individual bodies or "somata"), struggling not for geometrically arranged boundaries, but towards various other symmetries and a fixity in number of multiple parts. Paleontology thus contributes to biology by placing the oft-repeated comparison of life with crystallization in an entirely new light.

Relations to Sociology

It is to be noticed that when the extreme of bodily evolution had been reached by the production of a mammal, the final real advance in the world of life was a gradual increase in the effectiveness of the controlling nervous centre or brain. Then, for the first time in the history of the globe, brain rather than bodily state determined the survival of the fittest. In fact, it is clear that mental attributes have slowly arisen in obedience to the same laws which controlled the advance of the animal frame itself. Such being the case, it is not surprising that the highest use of these attributes by man should result in the arrangement of communities and methods of advancement which strictly conform to the laws discovered by the paleontologist. As Herbert Spencer, indeed, has well said, "All social phenomena are phenomena of life—are the most complex manifestations of life—must conform to the laws of life—and can be understood only when the laws of life are understood." In other words, the study of fossils has a distinct bearing on the problems of sociology.

The general resemblance between the evolution of human communities and animal groups is not difficult to perceive in any direction. In the progress of every nation there are clearly-marked periods of brilliance between others of comparative stagnation, corresponding with the rhythmic advance already described as observable among animals. At each period the real mental work and influence which lead to the next stage of progress are accomplished by a competent mediocrity, however much they may be consummated at intervals by the appearance of a guiding genius; in fact, the generalized rather than the specialized members of a community are the real groundwork of the future. Moreover, history seems to teach that every nation, on reaching

its prime, begins to display within itself the elements which lead to decline or extinction; so that it completes a definite life-cycle with an inevitable end. Indeed, even in smaller matters, it is often not difficult to express sociology in the terms of paleontology. Newberry, for example, long ago pointed out that the evolution of warfare between human communities corresponds exactly with that between fishes in the course of their long history—the first tendency being towards protection by thickening the armor until a maximum is reached, when this method is abandoned and skillful movement gradually supersedes it. Other examples might be cited, and will readily occur to any one who is familiar with the details of the past history of any group of organisms. It must, however, suffice now merely to conclude by emphasizing a remark made at the outset, that these wider aspects of the subject can only be fully appreciated when paleontology is taught and learned as an independent branch of knowledge.

ANTHROPOLOGY AND ITS LARGER PROBLEMS

BY WJ MCGEE

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YOUNGEST in the sisterhood of sciences, anthropology borrows principles and methods from all the older branches of knowledge; and her first problem—a problem renewed with each step of advance, and hence endless as the problem of quarry to the huntsman or of crop to the planter—is that of determining her own relations in the realm of knowledge, her own place and powers in the intellectual world.

Viewed in the light of history, it is no accident that anthropology is the youngest of the sciences; for it is the way of knowledge to begin with the remote and come down to the near—to start with the stars, linger amid the mountains, rest awhile among rare gems, and only slowly approach such commonplace things as plants and animals and soils, to end at last with man. *How* growing knowledge

has pursued paths leading from the remote to the near, from the rare to the common, from the abnormal to the normal, from the unreal to the real, from wonder to wisdom,—indeed, from chaos to cosmos and from start to man, —all this is history; *why* these paths have been pursued may well remain a problem until more is known of the constitution of the human brain and of the laws of mind.

Yet, viewed in the light of the relations among the sciences, it is no mere chance that the science of man rises from the hip and shoulder and head of the elder-sister sciences, as the family infant is borne by primitive folk; for the sciences have come up, just as the cosmos seems to have developed, in an order of increasing complexity. The stellar bodies are interrelated through gravity and various forms of molar force which may be combined under the term *molarity;* and astronomy in its earlier form was the science of these relations. As the planets took shape (whether through nebular integration or through planetesimal aggregation), chemical reactions became paramount over mechanical relations, and *affinity* was superadded to molarity; and in a parallel order chemistry was added to astronomy in the growth of knowledge. When our planet was incrusted, and the great deeps were divided into sea and land, life appeared, and thereby *vitality* was superadded to affinity; and concordantly, as knowledge grew, the biotic sciences followed the more exactly quantitative earlier branches. In cosmic time animal activity followed hard on more inert vegetal life, and *motility* was superadded to vitality; and in human time animals were domesticated soon after plants were cultivated, while zoölogy grew up nearly apace with phytology. As the earth aged into continental and seasonal steadiness, and the struggle for organic existence grew strenuous, more and more of the battles were lost to the strong and the races to the swift,

and were won by the intelligent, and thereby *mentality* was superadded to vitality as a factor in earth-history, and man came to his own as a mind-led monarch over lower life and a progressive conqueror of the natural forces; and in like manner, as human history matures, it records anthropology as the younger-kin of zoölogy. In a word, man, as the head and intellectual ruler over the realm of life, alone stands for all the fundamental forces of molarity *plus* affinity *plus* vitality *plus* motility *plus* mentality, and is interrelated alike with sun and planet, agent and reagent, plant and seed, egg and animal, and with groups of his own kind; and, in a word, the science of man is, more than any other branch of knowledge, interdependent with all the sister sciences, and more many-sided than any of the rest.

The Setting of the Science

The scriptless nomads of the human prime (and of many lands) set their journeys by the stars and enshrined their beastly deities in the visible firmament, and thus astrology set out on a course still traceable through constellations and planet myths; at the same time those mnemonic devices of the sky were mated with equally imaginative symbols of every-day things, and as these grew into geometric designs and arbitrary characters, a system of almacabala—the earth-placed twin of sky-set astrology—took a course still marked by the ancient hieroglyphs of many lands. In the fullness of time (and primitive progress was tedious beyond telling), astronomy grew out of astrology as the first of the sciences, leaving a large residuum of mythology behind. In like manner, and at about the same stage (*i. e.*, about the birth-time of writing), algorithm and algebra came out of almacabala, leaving a residuum of black art and white magic, jugglery and enchantment; and as the algorithm grew into arithmetic and wizardly geomancy

gave way to scholarly geometry, mathematics took shape as the compliment of astronomy—and these sisters twain were nurses and teachers of all the younger sciences. Still the caldron of inchoate knowledge boiled and bubbled with Macbethian pother, and the foul fumes of black magic long concealed the few germs of real knowledge shaped by the steady pressure of actual experience—for this was the time of alchemy, whose slimy spume at last slipped away from chemistry, the third of the sciences.

Astronomy led writing (as the constellations attest), while mathematics followed close on writing and records, as its symbols show, and both belonged to what may be called the Naissance of Knowledge; chemistry appeared during the same period, bearing the prophecy of physics caught by Archimedes, yet remained a helpless weakling—the foil and puppet of medievalism—throughout the whole of the Dark Ages; but during the Renaissance the trio of elder sciences gained strength together and assumed lasting dominion over the realm of knowledge. Because their birth dates back to or beyond the beginning of records, the early stages of these sciences are imperfectly written; but the youngest science, anthropology, buys methods and principles from the more exact elders and pays amply in coin of history; for by tracing the careers of later-born or slower-grown folk and cults, anthropologists learn to retrace the lost steps in the careers of ancestral peoples and early cultures. Here lie some of the relations between anthropology and the elder sciences; she receives exact methods tested by millenniums of experience, and gives interpretations of the ideas and motives, the arts and accomplishments, the modes of thought and the stages of progress, of the earliest science-makers. Astronomy and mathematics and chemistry are systems of knowledge produced by men and minds, anthropology is systematic knowledge of these producers;

and neither the old sciences nor the new can be rendered complete and stable without the support of the others.

The science of sentient man—of man as a thinking and collective organism—helps to illumine the Dark Ages no less than the Naissance of Knowledge; and at the same time it sheds new light on the origin of that group of modern sciences of which it is itself the youngest. The early period of intellectual activity in Babylon and Alexandria, Athens and Rome, may be likened to the blossoming of a plant in springtime; it was the summing and outshowing of a mentality shaped during uncounted generations of experience along definite lines, in environments of distinctive sort—and the blossoming was fuller of promise than the ancients dreamed. Then came the ages that were dark because energy was diverted to new lines; for leaders of thought gave way to leaders of action, and these became pioneers in new environments where threads of new experience had to be spun from the lives of generations before they could be woven into the fabric of knowledge. The forefathers of the joint founders of scholasticism and science lived winterless lives in sunny lands, and the early science reveals an elysian tinge; while the ancestry of the makers of modern (or natural) science spent their force in conquering wood-lands and wood-life in cloudy and wet and long-wintered Europe, and their efforts finally yielded a harder and more practical product than that of the earlier and easier time. During the nature-conquest of a millennium and more, the ideals of the elder masters seemed lost in a survival of astrology and alchemy, a survival so well recorded in growing literature as to stimulate a revival; yet the sense of the reality of things gained strength by exercise in the ceaseless contact with nature, while the oft-told magic was relegated to beldams and crones rather than reserved for rulers and high-priests as of old. The Renais-

sance revealed the influence of these centuries of nature-conquest and nation-planting which made the Europe of history; and its dawn showed that the seat of highest intellectual activity had slipped in the darkness from the sensuous shores of the eastern Mediterranean to the remote and rugged lands in which the world's richest blood and ripest culture were blent and pent against northern seas. The closest concentration of human strength was in Britain; the uttermost goal of conquest, the last resting-place of the conquerors of conquerors, where Cæsar might have wept for worlds, like Alexander long before; and here modern science began with Francis Bacon (1561-1626) as expounder. The Britannian Renaissance, coming so long after the Mediterranean Naissance, may be likened to the ripe-fruiting of a plant in autumn; for it followed the vernal blossoming after a tedious interval of scarce-seen growth.

With the *Novum Organum* of Bacon, the last vestige of magic and mysticism fell away from the body of real knowledge; for not only was the practicality of centuries summed in the new system, but its author saw more clearly than any predecessor the relation between the thinker and his thought, between the human mind and the rest of nature—he perceived that "Man. . . . does and understands as much as his observations on the order of nature. . . . permit him, and neither knows nor is capable of more." On this and kindred verities he built a foundation for all the sciences, for the unwittingly-wandering elders as well as for those yet unborn, even down to anthropology—though this part of the foundation lay unused for three centuries. Bacon's influence on contemporary and later thought was steady, albeit slow-felt; for his school was a normal by-product of the making of Europe, and he was the exponent of principles themselves the product of the world's most significant

chapter in human development. True, the next epoch was opened by a son of southern shores and a devotee of the oldest science, when Galileo (1564-1602) saw the sun-centred order of the solar system; yet it was left to English Newton (1642-1727) to shape the epoch and systematize all astronomy by a law of gravitation based on commonplace observation, while the third epoch of modern science came with Linné (1707-1778), like Bacon and Newton a product of the harsh northland and an exponent of practical experience, who led conscious seeing down from the stars to the plants and animals of daily knowledge. Of all the world's thinkers Linné would seem second only to Bacon in originality, if that quality be measured by grasp of realities; and while his system was crude, especially in relation to animals, his gift of phytology (or botany) enriched knowledge and opened the way for the rest of the natural sciences. Linné the Swede was soon followed by Hutton the Scot (1726-1797), with a practical science of the rocks long contested by Werner the German (1750-1817), under a theory smacking of Alexandria and Athens; but the sturdy English quarryman, William Smith (1769-1839), successfully supported his northern neighbor until his countryman Lyell (1797-1875) came up to make geology a science. The influence of these sons of woodland and wold extended rapidly and widely, rooting readily in the fertile minds of their kinsmen, while the printing-press spread the stimulus of their work over all Europe and unified the knowledge of the nations.

The next act attested the blending of the ancient and the modern, of Athenian and Anglian, of Aristotelian and Baconian, of the southern and the northern; and the scene was the middle ground of France. There Lavoisier (1743-1794) applied modern practicalness to chemistry, and discovered the indestructibility of matter; Lamarck (1744-

1829) sought to amend the Linnean system, yet pushed too far in advance of observation (and his times) for full following; and the brothers Cuvier (1769-1838) so improved on Linné as to give form and substance to zoölogy, and incidentally to presage anthropology. These movements led up to the distinctively nineteenth century stage, and a renewed pulse of British activity; Joule and others measured the mechanical equivalent of heat and experimentally demonstrated the persistence of motion, and so founded physics; by masterly observation and comparison, Darwin defined the development of species (including man), thus infusing the blood of life into the Linnean system; Huxley and Tyndall simplified all science by establishing the uniformity of nature; and at last American scions of Anglian sires independently discovered through anthropologic observation that the minds of all men of corresponding culture-grade respond similarly to similar stimuli, thereby proving the soundness and completeness of the Baconian foundation of knowledge. The four laws of nature established in western Europe—the Indestructibility of Matter, the Persistence of Motion, the Development of Species, and the Uniformity of Nature—are, in fact, complementary to the law forecast by Bacon and applied in America three centuries later as the Responsivity of Mind; and the five laws are the cardinal principles of science. It is curious that, while Bacon's view of the mind as a faithful reflex of other nature colored and shaped the progress of science through the centuries (for how could Lavoisier, or Joule, or Darwin, or Huxley repose confidence in their observations without resting even greater confidence on the accuracy of the observing mechanism?), the Baconian law lay in the background of thought without conscious expression (despite daily subconscious use) from the dawn of the seventeenth century down to the last quarter of the

nineteenth. *How* the law was neglected is the history of modern science read between lines; *why* it was neglected until the science of sentient man arose to rediscover it is a present problem for those anthropologists whose sympathies and interests cover the full field of human knowledge.

Howsoever the three-century eclipse of Bacon's fundamental law be interpreted, the history of science stands out sharp and clear when viewed in the light of anthropology. There were two great movements, the Naissance in the east-Mediterranean region, and the Renaissance, commonly credited to the Mediterranean countries, but really made in the North Sea region; each comprised a long interval of accumulation of experience and a briefer time of formulation of knowledge; in each the formulated knowledge faithfully expressed the habits and characters of leading thinkers of the times; and the modern movement reached the commonplace things of every-day life in such wise as to render science a devoted handmaid rather than a remoter déesse, a means of welfare rather than an end of aspiration. The anthropologist feels that the comprehensiveness of the ancient and the practicalness of the modern unite in his science, which (despite the narrow definitions of earlier decades) is that of mind-controlled man, the dominant power of the visible world, the science-maker as well as the subject of science.

Such are a few of the relations of anthropology to the sister sciences, a few of the ways in which the science of sentient man touches the sum of human knowledge; to catalogue all would be interminable.

The Rise of Anthropology

When the science of man grew up in the North Sea region, it was at first little more than a branch of zoölogy, and its makers busied themselves with features of the hu-

man frame corresponding to those of lower animals; comparative anatomy was cultivated with assiduity and profit, anthropometry flourished, and mankind were apportioned into races defined by color of skin, curl of hair, slant of eyes, shape of head, length of limb, and other structural characters—*i. e.,* the methods and principles of zoölogy were projected into the realm of humanity. It was during this stage that homologies between human structures and those of lower animals were established in such wise as to convince attentive students that mankind must be reckoned as the ennobled progeny of lower ancestry; true, the conviction grew slowly against the instinctive antagonism of the investigators themselves and the less effective (though louder) protests of contemporaries, yet the growth was so sure that the question of the ascent of man is no longer a problem in anthropology. Meantime the masters—and here Huxley and Darwin must always rank—gave first thought to normal and typical organisms; their disciples followed the same commendable course, and as other lines of man-study opened they called their work physical anthropology. One of the collateral lines reverted to the abnormal (in which knowledge commonly begins) and recurved toward the Mediterranean (where the influence of Alexandria and Athens still lingers), to mature in criminal anthropology—the science of abnormal man; another line led through prehistoric relics to archeology, and still another stretched out to the habits and customs of primitive peoples, and eventually to comparison of these with the usages and institutions of civilized life. The last of these lines was laid out in Britain largely by Tylor, and was pursued in Germany and other European countries as general anthropology, ethnography, anthropo-geography, etc.

Even before this growth began, a development not unlike that accompanying the making of Europe (save that

the progress was more rapid) was under way in America; for the pioneers not only pushed out into their wilderness like their forbears of generations gone, but faced the novel experiment of life in contact with savage or barbaric tribes. To this new stimulus their vigorous minds responded promptly; the daily experiences were quickly flocked on distaffs of thought, spun into threads of knowledge, and duly woven into a web of practical science—a fabric no less independent in the making than that of Bacon in his day. Notable among the American pioneers was Albert Gallatin (1761-1849), statesman and scientist; he not only perceived, like his fellows, that the color and stature and head-shape of the savages were of trifling consequence in contrast with their actions and motives, but that the index to their real nature was to be found in what they habitually did; and he summed American experience up to his time in a preliminary classification of the native tribes on the basis of language. This advice marked an epoch in science no less important than that of Linné; true, it was not minted at a stroke nor finished without aid from others, yet Gallatin was the coiner, and the rough-stamped system was history's most memorable essay toward the scientific arrangement of mankind by what they *do* rather than what they merely *are*. Later Morgan (1818-1881) extended practical observation to the institutions of the aborigines in such wise as to found inductive sociology;[1] and still later Brinton (1837-1899) made noteworthy advances toward classifying the Amerinds (*i. e.,* the native tribes) by their own crude philosophies, thus forecasting an inductive science now called sophiology. These advances seem simple and easy in the light of present knowledge, and may look small to present backsight, yet in originality of work and

[1] The speculative sociology of Auguste Comte (1798-1857) and the semi-speculative system of Herbert Spencer are to be noted merely as standing on somewhat distinct bases.

boldness of conception they rank with the advances of Linné and Lavoisier; and be it remembered that they were not borrowed in any part, but bought at cost of the sweat and blood of often tragic experience. The unprecedented practicalness of American anthropology is attested by the fact that, while Morgan and Brinton still wrought (in 1879), a governmental bureau was created to continue the classification of the native tribes; and its direction was instrusted to Powell, a master able not merely to occupy but greatly to extend the foundation laid by Gallatin. Under this impetus the new science progressed apace; American students multiplied; observations spread afar; each discovery prepared the way for others, and the new principles opened to scientific view the entire field of the humanities—that field aforetime claimed on one side by scholastic and statist, and held on the other by devotees of poesy and romance. The growing knowledge bridged the seas, and the Powellian product blent with that of Tylor (both profiting by the experiences of British India), and pushed on to several Continental centres during the last two decades of the nineteenth century.

Toward the close of the old century, what may be called the kinetic and collective characters of humanity were brought out clearly, and the American aborigines (with other peoples as well) were defined by the *activities, i. e.,* by what they *do*, and this collectively—for in the realm of humanity no one lives to himself alone, but all are joined in twos and larger groups. Now it cannot be too strongly emphasized that the basis of this definition differs fundamentally and absolutely from that of any other science; for all other entities—stars and planets, molecules and ions, minerals and rocks, plants and animals—are defined by what they *are* (perhaps measurably by the way in which they respond to external forces), while the humans are de-

fined and classed by what they *do* spontaneously and voluntarily as self-moving and self-moved units or groups. Necessarily this view of humanity awakens inquiry as to why the human entity stands in a distinct class among the objects of nature; yet this is hardly a present problem, since the makers of modern anthropology find full answer in that unique nature-power lying behind the kinetic character of unit or group, viz.: *mentality*. So in the last analysis the modern definitions of mankind are primarily psychic; and it matters little whether men are classed by what they *do* or by what they *think,* save that doing is humanity's largest heritage from lower ancestry, and hence precedes thinking; the essential point is that the practically scientific classification of mankind must rest on a kinetic basis, *i. e.,* on self-developed and self-regulated conduct.

Of late the activities themselves are grouped as arts, industries, laws, languages, and philosophies, and each group constitutes the object-matter of a sub-science, thus giving form to esthetology, technology, sociology, philology, and sophiology; and these (together called demonomy, or principles of peoples), with somatology and psychology, make up the field of *fin-de-siècle* anthropology—the last two corresponding respectively with the physical anthropology of most European schools and the strictly inductive mind-science of current American schools, while the first two include archeology as their prehistoric aspects. These outlines and partitions of the groups are essential, although in actual interest they lie beneath the full fruitage of the field, as a wire-hung skeleton lies below the sentient body athrob with vitality and athrill with consciousness of power over lower nature. This fruitage is too large and luxuriant for ready listing; it need now be noted only that, in the modern anthropology, sometimes styled the New Ethnology, the peoples of the world are not divided into races

(save perhaps in secondary and doubtful fashion) but grouped in culture-grades, and that these culture-grades are of special use and meaning, in that they correspond with the great stages of human progress from the lowly and unwritten prime to the brightness of humanity's present.

The culture-grades (and progress-stages) may be defined in terms of arts or of industries, of laws, of languages, or of philosophies, and the definitions will coincide so closely as to establish the soundess of the system, though it is customary to define them in terms primarily of law (or social organization) and secondarily of faith or philosophy. So defined, the grades (and stages) are: (1) Savagery, in which the social organization is based on kinship traced in the maternal line, while the beliefs are zoötheistic; (2) Patriarchy, or Barbarism, in which the law is based on real or assumed kinship traced in the paternal line, and in which belief spreads into pantheons including impressive nature-objects as well as beasts; (3) Civilization, in which the laws relate primarily to territorial and other proprietary rights, while the philosophies grow metaphysical and the beliefs spiritual; and (4) Enlightenment, in which the law rests on the right of the individual to life, liberty, and the pursuit of happiness, and in which the philosophy is scientific or rational, while the faiths grow personal and operate as moral forces. The peculiar excellencies of this classification lie in its simplicity, and in the fidelity with which it reflects the unique nature-power lying behind the kinetic character of the human entity, *i. e.*, mentality; for, in the last analysis, the stages but portray and measure the normal growth of knowledge. Thereby the system sets milestones in the path of human progress, in numbers sufficient to outline its trend with satisfactory certainty; and it is especially notable that this trend is from the lower toward the higher with respect to every distinctively human attribute.

So anthropology came up, chiefly on the western hemisphere and under the stimulus of unique and strenuous experiences; and so it has assumed form and substance and spread widely over the world during two decades past. Viewed from its own high plane, the growth of the science presents no puzzling problem; yet, since no mind leaps lightly from classification on a static basis (as in somatology and its parent zoölogy) to classification on a kinetic basis (as in demonomy), the modern aspects of the science are full of problems to some students.

Problems of Classification

While the essential characters of mankind reside in mind-shaped activities, it remains true that the mental mechanism is planted in a physical structure derived from lower ancestry by uncounted generations of development; and the problem as to the weight properly assignable to hereditary structural characters in classifying men and peoples remains, in many minds, a burning one. As an academic problem, this may be said to distinguish the new anthropology from the old, and to divide the anthropologists of the day into opposing schools, one chiefly American, the other chiefly European; as a practical problem of applied science, it has already engaged the attention of the world's leading statesmen (most of them approaching it empirically under the law that doing precedes thinking), and, with such help as they have been able to secure from science, they have solved it to their satisfaction, and have declared in numberless constitutional and statutory provisions that red and black, if not yellow men, share with whites the potency (at least) of enlightened citizenship, and should be led and aided and educated toward that goal despite the handicap of heredity. Here the highest statecraft and the most advanced anthropology strike hands; the statesman

argues from his own experience that lowly men may be raised up, and hence that it were heartless to strike them down; the scientist but sums more numerous observations when he traces the upward trend of humanity; and both stand firmly on the rock of experimential knowledge. True, practical questions involved in the general problem are constantly arising: Can the Apache at San Carlos best be led toward citizenship by penalties for misdeeds, by rewards for righteousness, or by a combination of the two? Does the hereditary structure of the Negrito of interior Luzon debar him from hope of free citizenship, including that rectitude of conduct and nobility of impulse which free citizenship requires? Can the fellahin of Egypt be lifted from the plane of subjection to despotism to that of intelligent loyalty as royal subjects? Will the educational qualification in Maryland elevate the franchise? These are among the multifarious and ever-rising questions involved in the problem; and while the old anthropology stands aloof, they are receiving yearly solution at the hands of modern science and modern statescraft. Fortunately this present problem of anthropology is no less practical than were those confronting pioneer Puritans and Cavaliers in an earlier century, and like those it must be wrought out through living experience; still more fortunately, the chief factors in the problem are now grasped by students taught in the severe school of the settlers—grasped so firmly that little remains undone save the bringing-up of loiterers who linger in the haze of half-knowledge and hearken idly to bookish echoes of simpler science.

Connected with this problem is another no less burning: Does the mental mechanism of mankind react on physical structure in such wise as to control the development of individuals and types? As an academic problem this is well-nigh lost in the dust of ill-aimed discussion (relating to the

hereditability of acquired characters and a dozen other points) which it were indiscreet to stir; yet half an eye can see that, whatsoever pedagogues proclaim, the pupils are building bone and muscle, increasing strength and stature, and manifestly promoting brain-power and prolonging life by judicious regimen. As a practical problem this might be passed over, since the world's leading millions are so well advanced in *doing* that *thinking* may be trusted to follow duly (perchance soon enough to let the masters learn the lessons their pupils live), were it not for the ever-rising ancillary questions as to rate and trend of the progress. Thus, mean length of life, or viability, is increasing, especially among more advanced peoples, who live longer in proportion to their advancement; yet, although Mansfield Merriman computed a few years ago that the median age of Americans has gone up five years since 1850, while the Twelfth Census reports that our mean age of death advanced from 31.1 years to 35.2 years in a decade, it cannot be said that the rate of increase is known; and still less are the factors of increase (saving of infants, improved sanitation, bettered hygiene, shortened hours and intensified stress of labor, enhanced enjoyment of life, and all the rest) susceptible of statement in terms of definite quantity. The various questions of viability (than which no inquiries mean more to living men) are not to be answered through actuaries' tables based on selected classes, valuable and suggestive as these tables are; they must be answered through health offices and census bureaus—and their pressing importance forms one of the strongest arguments in support of permanent census bureaus in this and other countries. Thus, again, human strength is increasing, as suggested by the superior vigor and endurance found among advanced peoples and rising generations, and shown definitely by the constant breaking of athletic

records; yet, while it is most significant that record-breaking progresses at an increasingly rapid rate (*i. e.*, more records during each decade than during the last), the rate of increase remains problematic. Similarly, that measure of faculty expressed in coördination of mind and body is increasing, as shown by the ever-growing and never-failing ability of engineers, mechanicians, builders, electricians, and other specialists to master and command the strength-trying devices of modern times—locomotive and marine engine, dynamo and steam hammer, range-finder and machine-gun, and all the rest; yet both the rate and the factors of increase in human faculty remain in the realm of the unmeasured. These are but sample questions ancillary to the practical problem as to the reaction of function on structure; they merely suggest ways in which mind born of body in humanity's prime is rising into dominion over fleshly organ and constitution as well as over subhuman nature—and these ways remain for the future to trace.

A related problem, although minor in itself, has recently risen into prominence through the impetus of importation oversea; it is that of "degeneracy." The observational data for the idea of human retrogression are apparently voluminous (though seen to be mainly of opposite meaning in the light of modern human knowledge) and the notion is by no means new; but the ratiocinative basis of the recent fad is obviously chaotic, *e. g.*, in that an individual is classed as "degenerate" by reason of the inheritance of ancestral characters, or, in other words, because he is no better than his sire or grandsire. True, if normal man is rising to successively higher planes of physical and mental perfection through constructive exercise, as modern anthropology so clearly indicates, the unfortunate who is no better than his ancestry is indeed below his proper place in the scheme of humanity—though not degenerate, but merely unregenerate

(in non-ecclesiastical sense). It is also true that maleficent exercise may produce cumulative and apparently aberrant effects, just as does the beneficent exercise normal to mankind, the one yielding Nero and Billy the Kid as the other Shakespeare and Bacon (twin luminaries of intellectual history); but its end is destruction, with the consequent elimination of the criminal, while its middle merely marks lower layers in the constantly ascending stream of humanity. Naturally a theme filling tomes and flooding lighter literature for years is too large for full analysis in a paragraph; it must suffice to note that the "degeneracy" of the day was not unfitly characterized even so early as when aphorism foreran writing, and the proverb beginning "Put a beggar on horseback" gained currency. The great facts are (1) that less vigorous individuals fall short of the mean progress of their fellows in such wise as to get out of harmony with the institutions framed by their leaders, and (2) that less vigorous peoples fall behind contemporary lawmakers in such wise that their institutions are inferior to those of progressive nations; while under the conditions of modern life laggards and leaders commingle so freely that the differences are emphasized and kept in mind. Nor are these differences slight or meaningless; they touch the very fiber of living and being so deeply that primal savages cannot share the thought of those in any higher culture-stage, that barbaric serf and despot are wholly alien to subjects and citizens, and that subjects are out of place among citizens. So every advanced nation has its quota of aliens through foreign or ill-starred birth and defective culture, who can be lifted to the level of its institutions only through a regeneration extending to both body and mind, both work and thought—they are the mental and moral beggars of the community, who may not be trusted on horseback but only in the rear seat of the wagon. In truth, standards are rising so rapidly that the lower half find it hard to keep up.

In one aspect the problem of the unregenerate is ever pressing, since knowledge is not yet a birthright (save in the promising germ of instinct) among human scions of lower ancestry; but even in this aspect a progressive solution is wrought with ever-increasing success through public education. The most serious side of the problem arises in the immigration or upgrowth of the unfit, who sometimes ferment in the unwholesome leaven of anarchy before education has time for perfect work; and this danger cries out for public action through the blood of both presidential and monarchical martyrs to public duty. The morbid view imported by Nordau and his ilk demands little American notice, however large the problem in Europe; for under the stimulus of that personal freedom which is the essence of enlightenment, normal exercise of mind and body springs spontaneously, while hereditary disease, constitutional taint, idiocy, unhealthy diathesis, and all manner of transmissible abnormalities tend to wear themselves out, as our vital statistics sufficiently show.

These are a few of the present problems of anthropology involved in classifications growing out of the dual nature of mankind—the physical nature inherited from lowly ancestry, and the mental nature (in all its protean aspects) built up through exercise during uncounted generations of functional development. They may seem irrelevant to that earlier anthropology which is content to define mankind by skulls of the dead; but they illustrate the living importance of that modern science which defines mankind by actions and thoughts, movements and motives.

Meaning of Activital Coincidences

About 1875 archeologists, and after them students of primitive folk still living, became impressed with certain similarities among industrial and symbolic devices of re-

mote regions. One of the widespread devices is the arrow; used commonly with the bow, sometimes with the *atlatl*, or throwing-stick, and again as a dart projected by the hand alone, it has been found on every continent and in nearly every primitive tribe. Another is a quadrate or cruciform symbol; either in the form of a simple cross or in that of the cross with supplementary arms known as the *swastika* or *fylfot*, these symbols are common to Europe, Asia, Africa, both Americas, and numerous islands, though they have not been found in Australasia. At the outset such devices were accepted as links in a chain of supposititious relationships, and as suggestions of common origin of both devices and devisers; but as observations multiplied, the hypothetic chain broke beneath its own weight, for the few similarities were gainsaid and far outweighed by numberless dissimilarities of a sort manifestly attesting independent development. About 1880 Powell summarized the observed resemblances and differences among devices, and showed that the former are to be regarded as coincidences due to the tendency of the human mind to respond to contact with external nature in a uniform way. A dozen years later Brinton re-summed the growing data and corroborated the Powellian conclusion; and on extending the inquiry to institutions, forms of expression, and types of opinion and belief (in which the coincidences are even more striking than in the material devices), he formulated a theory of "the unity of the human mind," in which he saw a suggestion that the mind was extraneous in origin, *i. e.*, impressed on mankind from without,—a view not unlike that long maintained by Alfred Russell Wallace. With the setting of the old century and the dawn of the new, the ever-multiplying facts were again reviewed, and the earlier generalizations were again sustained, but found to tell less than the whole story; for it was discovered that, while minds of

corresponding culture-grade commonly respond similarly to like stimuli, minds of other grades frequently respond differently—as when the savage eviscerates an enemy and devours his heart as food for courage, or the barbarian immolates a widow on the bier of her spouse, or the budding Christian lends himself to the tortures of the Inquisition, each reveling in his own righteousness and reprobating all the rest, though all are alike ghastly and obnoxious to enlightened thought. The new generalization rendered it easy to define the limits within which the responses of different minds to similar impressions may be expected to coincide; thereby it cleared away many of the anomalies and apparent incongruities among the observed facts, thus strengthening the law of activital coincidences as first propounded. The introduction of a limiting term also rendered the law more specific; so that the sum of knowledge concerning the relations between mind and external nature may now be expressed in the proposition: *Minds of corresponding culture-grades commonly respond similarly to like stimuli.* By far the most important effect of the new generalization was the inevitable recognition of a cumulative mind-growth in passing from savagery to barbarism, thence to civilization, and on to enlightenment; for, in the first place, this recognition afforded a key to—indeed, a full explanation of—the sequence of the culture-grades, while, in the second place, it showed forth the course of the world's mental development as a growth no less natural than that of tree or shrub, originating within, conditioned by external environment, and not derived from any extraneous source. Thus the generalization in 1900 of a quarter-century's observations on mankind brought empirical knowledge to the theoretical plane so masterfully projected by Bacon three centuries before—for he it was who first grasped the great concept that mind is at once product and mirror of other nature.

Is the Baconian foundation for all science sound; is the most sweeping generalization of anthropology safe? This problem—for the two questions are but one—is the most important presented by the science of man, indeed, by all science; for it threads the whole web of human knowledge, touches every human thought, tinctures every human hope, tinges every human motive. True, it is too large for easy apprehension, too round for ready grasp; but it spans the world's intellectual structure from corner-stone to dome, and must sooner or later be wrought out personally (as are all problems in the end) by every rational being.

Problems of Distribution

Anthropology arose in Britain as a branch of biology fertilized by the doctrine of organic evolution; it grew up in a field of thought dominated by a tradition of human descent from a single pair and shaped by the habit of tracing nearer ancestry to the worthier sires in otherwise neglected lineage, and the coincidence of the doctrine of differentiation with revered tradition and honorable regard for honored sires led naturally to an assumption of monogenesis. The assumption spread and pervaded the writings and teachings of anthropologists trained in the biologic school; it still prevails, and is still supported by the argument from biology, though Keane and others have balked at the corollary that wavy-haired White, kinky-haired Black, straight-haired Red, and variable-haired Brown nestled in the same womb and sucked at the same breast. It is needful to note that the assumption, albeit perfectly "natural," is purely gratuitous, and that it is not sustained by a single fact in anthropology as a science of observed and observable actualities: the Blacks are not growing blacker, the Reds are not blushing redder, no new races are arising, no old types are increasing in diversity; Graham

Bell's note of warning against the danger of a deaf race advertised a solitary definite suggestion of the formation of a new human type, though even this seems to weaken with the lapse of time; indeed, it cannot be two strongly emphasized that, however besetting and enticing the hypothesis of differentiation or diversification of *Homo sapiens* may be, it is absolutely without direct observational basis.

When practical anthropology arose in America, it was seen by Gallatin and Morgan and other pioneers that languages and social usages tend to spread among contiguous tribes; and as Indian students advanced, it was perceived that the tendency toward activital interchange extended also to arts and industries and myths, and had, indeed, resulted in the development of powerful federations (somewhat miscalled "nations"), such as the Iroquois League and the Dakota Confederacy. Meantime it was observed that the spontaneous interchange of words and weapons, usages and utensils, with contiguous tribes was sooner or later accompanied by intermarriage, so that blood and culture blent at once. Of course this observation merely reflected the unwitting experience of every generation among every people in every land; but, made as it was under the stress of practical problems of polity and peace, it awakened consciousness—and the *law of convergent development* among mankind was grasped. Once realized, the law was found of wide application; it was perceived that black folk are not growing blacker, nor brown men browner, nor red tribesmen redder, because (among other reasons) some interchange of culture and blood begins with first contact and increases with time, until at least some of the leaven of the highest humanity pervades the lump, while the ideals and standards of all progress toward unity; it was perceived that the types of *Homo sapiens* (*i. e.,* the "races" of mankind) are not differentiating, because of that

irresistible mimetic impulse which is the mainspring of elevation, especially among the lower and measurably among the higher; it was perceived that culture is fertilized by contact with other culture more effectively than in any other fashion; and it was perceived that when the initial differences are not too great, blood fertilizes blood in such wise that the vigor of a people may be measured by the complexity of their interwoven strains—that Briton yesterday and American to-day led and still lead the world because the blood of each streamed up from a more varied group of vigorous sires than that of any earlier scion. The themes of culture-union and blood-blending are too broad and deep for treatment in a paragraph; yet it must be affirmed, with an emphasis which can hardly be made too strong, that these are the dominant factors of human development, and that this development, so far as actually observed, is always convergent, never divergent.

Now it is a logical corollary of the law of convergent development that mankind were originally more diverse than now, and hence that there must have been several *loci*, or centres, of human origin; and this corollary leads to a theory of polygenesis, which has been much discussed during a decade or two. Some of the polygenesists, like Keane, are content with four original stocks, corresponding respectively to the white, black, brown, and yellow "races" of mankind (leaving the red man, or Amerind, to be interpreted perhaps as a migrated branch of the brown stock); others, like Powell, find it easier to think of an indefinitely large number of initial stocks and centres of development from a hypothetic prototype to the "human form divine"—a prototype represented perhaps in a particular place by the famous fossil from Java, the *Pithecanthropos erectus* of Dubois. The alternative hypothesis is that of the monogenesis assumed in the early days of man-science; and the

choice—or adjustment—between these opposing views is one of the most prominent among the present problems of anthropology. The great facts are (1) that all known lines of human development are convergent forward, and hence divergent backward, and (2) that all well-known lines of biotic (*i. e.*, subhuman) development are divergent forward; *how* these incongruous lines are to be united across the dark chasm of that unknown time when man became man, remains a question only made larger thus far by each advance of knowledge.

The Problem of Humanization

To the comparative anatomist the gap between simian structure and human structure was of little note, even be-before it was divided by the Dubois discovery in Java; for the differences between higher apes and lower men are less than those between either (1) lower and higher apes, or (2) lower and higher men. Yet to the sympathetic student of mankind, these dead homologies are but unsatisfying husks; the great fact remains that even the lowest savage known to experience is human—man—in attitude, mien, habits, and intelligence, while even the highest apes are but bristly beasts. It were bootless to deny or decry the chasm separating the always human biped from the always beastly quadrumane, since it is the broadest in the entire realm of nature as seen by those who appreciate humanity in its fullness. *How* the chasm was crossed, either in the one place and time required by monogenesis, or in the many places and times demanded by polygenesis, is a question of such moment as to rank among the great problems of anthropology until (if ever) the solution is wrought. A tentative solution has indeed been suggested in the modified form of mating which must have attended

the assumption of the erect attitude;[1] yet final solution awaits the future.

The Problem of Human Antiquity

So long as the assumption of monogenesis prevailed, the question of the antiquity of man loomed large in the minds of students, while even under the hypothesis of polygenesis the date (geological or historical) of advent of the earliest man is of no small interest. So the discussion of human antiquity has grown into dozens of full volumes, hundreds of chapters, and thousands of special papers, not to include the tens of thousands of ill-recorded scientific utterances and literal millions of press items. This vast literature is not easily summed; it must suffice to say that the evidence seems to establish the existence of man in Asia and Europe and northern Africa during later Tertiary times, and thus before the glacial periods of the Pleistocene; but that the earliest Americans lagged behind, coming in probably before all the ice-periods closed, possibly nearer the earlier than the latest. Despite the wealth of literature, there is a woeful dearth of definite knowledge concerning the date or dates of man's appearance in different lands; and herein lies another of the present problems of anthropology.

Such are some of the larger problems of anthropology, that youngest science whose field touches those of all the rest. The smaller problems are legion; those of general sort are at once problems of science and of statecraft, of the daily life and welfare of millions, of greatest good to the greatest number. Fortunately all are such as to be solved by the slow but sure processes of observation and generalization; and it is especially pleasing to see—and to say—that these scientific processes are more steadily and successfully under way now than ever before.

[1] *The trend of human progress, American Anthropologist,* Vol. I. p. 418, 1899.

THE PROBLEMS OF ARCHEOLOGY

BY GEORGE EDUARD SELER

(*Translated from the German by Dr. George Kriehn, New York.*)

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IN this distinguished assembly, gathered in the place where all the material labors of the world have contributed their results to form a picture whose brilliancy can hardly be surpassed, and to which chosen representatives of all the sciences have been bidden in order to present in one harmonious whole the varied intellectual achievements of all nations, I am asked to speak of what has been accomplished of late years in my own department, that of archeology, and to lay before you the significance for the other sciences of these results.

There is scarcely any science to which coöperation with the others is so necessary as it is to archeology; yet there is scarcely one which in so short a space of time has gained so much in substantive importance, has entered so much into the work of the others, and has so demonstrated its usefulness to their progress. This is equally true of prehistoric European and classical archeology, and of the study of the antiquities of America. To look first at merely external facts, who would have thought it possible a hundred years ago that to-day in all parts of Europe hundreds of

museums would exist, filled with the domestic utensils, weapons, vessels, and ornaments of peoples from whom no historical knowledge of any kind has come down to us—some of whom, indeed, go back to a period whose antiquity can only be computed by the calculations of geologists, when the vine-clad hills bordering the Rhine and the Lake of Constance were barren as the steppes and tundras of Siberia, when the reindeer, the wild ass, and the mammoth served as objects of the chase and at the same time gave men the first impulse towards the satisfaction of their artistic feelings? You will be told by those whose province it is how classical studies have been enlarged and reshaped by the results of the science of the spade—how the excavation of the ancient seats of civilization in Babylonia and Egypt permit whole vanished worlds to rise anew before our eyes. My task is to give you, in a brief and summary way, an idea of what we have gained from the most recent investigations in the continent upon which we are now assembled,—that old continent which we, the children of another, have been accustomed to call the New World.

To begin with the North: it is too early to speak of archeology here as a separate science. The discoveries which have been made are the work of expeditions sent out for the solution of geographical problems or for the accumulation of collections to serve for the study of natural history or ethnography. Yet some facts of great historical significance may be deduced from the objects, not at first sight remarkable, which form the contents of the ancient graves of that region. We are entitled to infer, in the first place, that the existence founded upon the life of the Arctic fauna and adapted to it,—that of the Eskimo as they were first seen by Europeans, with all their peculiar civilization, their extremely clever adaptation of the wretched materials at their command to the making of weapons, utensils,

houses, boats—must have gone on in practically the same form for a thousand years at least, and probably much longer. Another fact of importance may be mentioned as the immediate result of combined archeological and topographical expeditions, especially those from Denmark and from Sweden and Norway. It is that the migration of the Eskimo to Greenland must have gone by way of Ellesmere Land and the northern coast of Greenland, down the east coast, and thus to the west coast. If, now, we take with this the statements of the Icelandic sagas that the first settlers in Greenland found remains of the houses of the Skrällings,—the small race which about the year 1000 inhabited the coasts of Labrador, Newfoundland, and Maine,—and that it was some of these same Skrällings who finally overthrew the important settlements of the Icelanders in Greenland, two further noteworthy facts emerge: that the Eskimo must, at a distant period, have spread southward at least as far as the coast of Maine, and that in various waves of migration, separated by intervals of time, they must have pressed on by the far northern way already mentioned, as far as the western coast of Greenland.

To-day the northwest, with its deep-cut fjords, its streams abounding in fish, and its wooded shores, is inhabited by a number of tribes who differ considerably in language, but show a remarkable similarity not only in their material civilization, but in their legends, their social organization, their religious conceptions, and the artistic productions based upon them. As to that which is the most distinctive thing in this ethnographic group, the social structure and what depends upon it, Professor Boas has recently shown that it really represents quite a late type of development. The archeological explorations made by the Jesup expedition not long ago in this and the neighboring regions seem to yield the interesting fact that all these tribes were

forced outward from the interior to the coast at a period perhaps not very remote.

In the central and southern portions of the United States, great triumphs have been won by archeology. Since Squier and Davis published their celebrated book, their work has been energetically taken up by the Peabody Museum, the Smithsonian Institute, and a number of other learned societies, and carried forward with great success. The valleys of the Ohio and the Delaware, Wisconsin, and the Lake region, the Mississippi Valley, the neighborhood of this very place, which proudly calls itself the "Mound City," the Alleghanies, Georgia, Florida, have yielded an immense number of objects of the most interesting nature. For their preservation and scientific study, museums have grown up in many American cities, whose well-adapted and liberal equipment has roused the admiration of scholars. Through these discoveries, the meager accounts given by early writers of the Indian tribes who inhabited these fertile plains at the time of the first white settlement—accounts which, to say nothing of their marked tendency to exaggeration, plainly correspond with but little faithfulness to that which lay before the eyes of the writers—have received for the first time their proper elucidation. For it seems to be firmly established by the exhaustive investigations of the last few decades that it was the ancestors of the Indians of to-day who were buried in the mounds, sarcophagi, and graves; that it is their domestic utensils, their ornaments, their ceremonial and social symbols, their instruments of worship, which we contemplate with astonishment to-day in the various American museums as objects discovered in the mounds. That the condition of material, and perhaps the intellectual advancement, was distinctly higher than that of the Indians with whom the immediate ancestors of the present generation had to contend, may be seen at once from

these discoveries. But the nature of the discoveries shows us also that among them every man's hand was not always, as people have been accustomed to suppose, against every man,—that rather, in spite of all their wars, there was a wide range of predominantly peaceful intercourse. We frequently find in one and the same spot copper from the Great Lakes, mica from the Alleghanies, mussel-shells from the Gulf, pieces of obsidian from the Central Basin, and snail-shells from the Pacific. If, however, the old theory of a special race of mound-builders has long ago had to be abandoned, a significant displacement of the tribes undoubtedly occurred, none the less; and it is not impossible that whole tribes have disappeared from the face of the earth, and speak to us only in the fragments that we dig up. Philology (in the critical analysis of local names), archeology, and history will have to work together in order to furnish even an approximately correct idea of the former distribution of the tribes and of their mutual relations.

It is primarily from archeology that we may expect an answer to the question where was the old racial connection between North America (perhaps with Florida for a bridge), the West Indies, and South America. The fruitful investigations of Clarence B. Moore and the lamented Cushing afford matter for much thought. Unfortunately, the exact archeological investigation of the West Indian region has only just begun. And, although remarkable discoveries have been made on the island of Marajó and the banks of the Amazon opposite to it, yet the investigation as to South America also is still too incomplete for us to do more (with that of the intervening territory hardly even planned out) than make a conjectural statement as to any extensive connection. There are certain single details—such as the Haitian game of *batey,* resembling the game of ball called *tlachtli* by the Mexicans, the use of some of the Mexican

teponaztli, similar wooden drums, and the like—which seem to point to a connection between the West Indies and Central America. Indeed, Columbus, on his first voyage, during the passage from Cuba to Haiti, had definite news of a land in the west, very rich in gold, whose inhabitants wore clothes. It seems to me, too, that it is possible to demonstrate a family connection between the Arawaki speech of Guiana and the Maya tongues.

But American archeology is most at home in the lofty plateaus of the Andes and the strips of coast immediately below them, and especially in Mexico and Central America. In these regions, inhabited by people of advanced culture, brilliant performances were achieved in the first generation after the conquest, which have only within the last half century been properly appreciated and studied in detail. In the seventeenth and eighteenth centuries, it was the scene of the labors of some accomplished scholars, such as Siguenza y Góngora. Padre Antonio Alzate published a description of the pyramid of Xothicalco; and Leon y Gama, in his famous work *Dos Piedras,* described the great stone monuments found in the principle square of Mexico in connection with the paving and canal system. The imposing personality of Alexander von Humboldt attracted the interest of the whole civilized world to these antiquities; and men like Captain Dupaix, Alaman, Carlos Maria Bustamante, Fernando Ramirez, Manuel Orozco y Barra, and my esteemed colleague Alfredo Chavero have laid the foundations on which we are now trying to build. Here, more than elsewhere, it is evident how much history needs the aid of archeology, especially to fill the large gaps which tradition, defective and dependent on chance as it is, has left.

About the middle of the sixteenth century appeared the great work of Fray Bernardino de Sahagun, an encyclopedia of the traditional knowledge possessed by the old inhabi-

tants of the capital of Mexico, written down from the lips of the natives and in their own language. To about the same time belong the notes of Fray Toribio de Benavente, who called himself by a Mexican name, Motolinia, "the poor man." These, while not nearly so extensive or so thorough as Sahagun's, and written in Spanish by a Spanish monk, have an importance of their own; living far from the capital, Padre Motolinia knew and described conditions prevailing in a much wider region. The original work of Sahagun disappeared in the archives of the Consejo de Indias, but copies of the Spanish translation existed in the libraries of the Franciscan houses. These, as well as the book of Motolinia and other sources, were recast by Torquemada and others according to the taste and the interests of their own times, until Clavigero brought together all the antiquities of Mexico in a cleverly written book which formed the main authority of Humboldt and his successors. That we have now got far beyond the diluted, frequently inexact or actually distorted idea given by this author is due not only to our having gone back to the real old sources, which have come to light since his time, but also to the elucidations which archeology furnishes. The meritorious publications of Lord Kingsborough made possible the real study of the Mexican hieroglyphs, as it was first attempted by Dr. Antonio Peñafiel. The descriptions and drawings of the Sahagun manuscript taught us to know the figures of the gods; and by their aid we are able also to identify the stone images and the small clay figures which the old Mexican collections contain in such numbers. Finally, both through them and through the interpretations appended to the Codex Telleriano-Remensis and the Vatican Codex 3738, we are able to decipher the pictorial representations of the manuscripts of the Codex Borgia group and the Mexican picture-writing in the narrower sense, and so to

secure a safe basis for studying the religious and festival tradition of the Mexicans.

Just as here archeology and history supplement each other, so recent observations have shown that the descriptive ethnology which appeals to surviving representatives of old tribes has need to keep archeological facts before its eyes during the progress of its researches. A few years ago expeditions were sent out by one of the great American museums into the Sierra Madre of northwestern Mexico, under the leadership of the explorer Karl Lumholtz. The undertaking was successful in more than one respect. Among its most interesting results was the fact that in the Huichol tribe Lumholtz found and was able to study a people that was still living in, or had relapsed into, almost primitive conditions. I read at the time with great interest, as did every one else, the account which Lumholtz gave of this tribe; but it was plain to me at the first glance that a large number of customs, signs, and symbols really could not be understood without comparison with the exact descriptions of the old Mexican sources and a knowledge of old Mexican symbolism.

The same is true of the peculiar province of the Pueblo civilization. In regard to this the investigations have not yet gone very far. The first attempt was made by my friend, Dr. Walter Fewkes, who tried to explain the famous snake-dance of the Hopi Indians by the cognate ceremony of the old Mexican *atamalqualiztli*. On the other hand, it is equally true that the meaning of the old Mexican festal ceremonies, figures, and symbols can only be reached when we have succeeded in determining that of the various festivals of the Pueblo Indians, of the ornamentation which is still used by them, and of the decorations which we are able to study on their utensils and fragments as found by excavators. I have purposely made this distinction between

what they use to-day and what we see on the old pieces; for the whole curious world of the Pueblo Indians of New Mexico and Arizona, which has aroused the special interest of investigators and travelers, is itself only intelligible when we study it in the light of archeological discoveries. The cliff dwellings are not only the precursors of the *pueblos* of to-day, with their houses built up one above another, like fortresses, in curved lines, but they explain them. The peculiar subterranean chamber for worship, the *kibva*, is understood when we see the narrow space there is in the overhanging rockshelters. We cannot, of course, dig up the festivals and dances whose survival, like a curious fossil, gives us so instructive a picture of the primitive conception of the world and primitive religious practices adapted to the special daily needs of the community; but the types which appear in them are to be found in many of the ancient rock-sculptures of the district or on the singular painted plates which have been found in some of the deserted *pueblos*. Their system of ornamentation, again, will only be fully understood when we can subject to a thorough comparative examination the old models, as they may be so admirably seen, *e. g.*, in the vessels and platters dug up in Awátobi.

An example of the way in which only the data furnished by archeology supply us with the solution of a problem is given by the development of our knowledge concerning the hieroglyphic writing of the Maya tribes of Central America. Through Bishop Landa, the oldest chronicler of Yucatan, we had learned to know the hieroglyphics of the twenty signs for days and the eighteen for the so-called months, or periods of twenty days (*uinal*). The further example. given by Landa, of a real hieroglyphic character by which Brasseur de Bourbourg and others believed they could read the hieroglyphic texts, has proved to be a mystification, or an attempt made in later and Christian times, from which

nothing was to be gained for the understanding of the old texts. More recently, Schultz-Sellack and De Rosny identified the hieroglyphs of the signs of the zodiac. Förstemann, with the insight of genius, got hold of the numeral system and the characters used for it in the Maya manuscripts, and gave us the hieroglyph of Venus; and Schellhas established a number of the hieroglyphs of the gods. I have myself shown the essential identity of the day-signs used by the Maya and in Mexico, the hieroglyphic designations of the colors and other elements, as well as a number of further hieroglyphs of the gods and the symbols which accompany them. But that we are able to-day to recognize at the head of the hieroglyphic columns the numeral products which give the distance of the following date from the original initial date demonstrated by Förstemann, four *ahau,* eight *cumku,* and that in consequence we are able to fix the chronological order of the whole series of monuments; this has been rendered possible by the labors of Alfred P. Maudslay, through the synopsis of the "initial series" which he has given on a page of his splendid book on the monuments of Copan in Honduras.

But archeology is especially needed to fill out the gaps left by historical tradition. The early historians, especially the conquering Spaniards, occupied themselves principally with the tribe which at the time of the conquest held the headship. Of the other tribes, their past, their frequently quite distinct material and social civilization, only comparatively scanty accounts have been preserved. The filling-out of these gaps is only to be hoped from archeology, which has already made very promising beginnings. In the central portion of the state of Vera Cruz the excavations of Dr. Hermann Strebel have permitted us to recognize two entirely distinct civilizations, one of which, the Cerro Montoso type, is indisputably allied to the artistic style of the high-

land Mexicans of the Cholula district, while the other, the Ranchito de las Animas type, shows, both in material and technique and in ornamentation, a totally distinct form, betraying a specially aboriginal element. Archeology thus confirms the assertions of history in regard to the extension of the highland race of Chichimos, a race of Mexican speech, into the coast-strip inhabited by the Totonacs. In like manner, further north, my wife and I found a settlement at Castillo de Teayo, in a district all around which the Huaxtecs had taken possession, where we met with Mixcouatl, the hunting-god, Chicomecouatl, the goddess of corn, Tlaloc, the rain-god, Couatlicue, the water-goddess, Xipe Totec, the earth-god or spirit of the fields, and Macuil xochitl, the god of chance,—all well-known types of the Mexican highlands; and reliefs were cut on stone plates which seemed almost copies of the Magliabecchiano Codex, the old Mexican picture manuscript of the Biblioteca Nazionale at Florence. The accounts given in Tezozomoc's *Crónica Mexicana,* of warlike expeditions of the Mexican kings by way of Huauhchinango into the lands of the Huaxtecs from Tziuhcouac and Tochpan, were now intelligibly verified. To the south of Vera Cruz Hermann Strebel has demonstrated another distinct element of population in the Mistequilla, the district of Tlaliscoyan, which presumably corresponds to the Olmeca Uixtotin of Mexican tradition,—clay figures with broad, smiling faces and artistically shaved patterns on their heads, of which the Musée du Trocadéro has the richest collection among European museums. Next come the districts, not as yet thoroughly investigated from the archeological standpoint, of San Andres Tuxtla and Coatzacualco; and at Tabasco the Maya region begins, with its wealth of monuments, stone buildings, façades covered with reliefs, and the long series of calculiform hieroglyphics which lend themselves to such

effective decorative arrangements. An then suddenly appears, in the midst of this definitely Maya civilization, in the famous ruins of Chich'en Itzá in eastern Yucatan, a style of figures and a hieroglyphic which correspond to those of the Codex Borgia group and the group typified by the Vienna manuscript; with snake columns and caryatides reminding one of those of Tula, the famous old centre of civilization, already ruined at the time of the conquest, and connecting with the legends of the Toltecs, the oldest civilized race found on Mexican soil. Désiré Charnay observes that here we have in concrete form the accounts of the wanderings of the Toltecs towards the coast-lands, the stories of the *tlamatinime tonatiuh iixco yàquê,* the wise men whom their god directed to go to meet the sun, *i. e.,* towards the east.

The districts already described, lying around the Gulf of Mexico, form but a small part of the region inhabited by civilized races. Further investigations are still lacking to carry us along the road which leads from the old trade centre of Xicalanco to the Laguna de Términos over the Petén into Central America. And we are still imperfectly informed as to the routes by which the merchant caravans from Cholula and Mexico made their way to Anauac Xicalanco, the lands along the gold-coast, and on the other side to Anauac Ayotlan, the coast-strip on the Pacific, and to Guatemala. But when this whole territory has been more thoroughly explored, with the care to which European investigators are accustomed, we shall get a far more complete idea of the mutual relations of the tribes; and then for the first time it will be possible to write the ancient history of Mexico.

The region comprising Mexico and Central America is that in which American archeology is best able to rise above the standpoint of merely antiquarian investigation, and to

attempt higher tasks. The question is yet unsolved whether the first appearance of what we call decoration is to be taken as a significant marking, as an inscription, so to speak, which is intended to place the object in relation with another being or object, real or imaginary; or whether a purely artistic impulse guided the hand of the first man who painted or carved an ornament of any kind, or worked itself out in the technique of weaving and plaiting. But we may take it as certain that we shall have to go back to a very early period, a stage of development not far removed from the general beginning, in order to trace the transition from merely useful tools to ornamented ones, the development from a simple marking, significant according to its meaning, to real ornament which owes its origin to a delight in form and color. There is a particular charm in trying to discover these first beginnings of primitive art. But in the Mexican-Central-American region this initial stage has long been passed. We meet here with productions, which, even if they are not to be placed beside the classical work of Greek artists, are yet, in conception, in the tasteful distribution of ornament, and in form, entitled to the designation of works of art. I need only remind you, for example, of the graceful arabesques of the borders on the sculptured walls of the temple of Chich'en Itzà, and of the hieroglyphic pictures, put together in a small space with such perfect art, of the *stelae,* altar-tablets, and other reliefs of Copan, Quiriguá, Palenque, and the ruined sites of Usumacinta, which the works of Maudslay and Teobert Maler have taught us to know. That the purely esthetic way of looking at things is beginning to gain ground in American archeology also is evidenced, for example, by the latest work of Hermann Strebel; and it is undoubtedly to be expected that before long this branch of science will have more work put on it, and that by its means some valuable

results for the historical classification of the monuments will be attained.

The special traits of the old Mexican and Central American civilization, and the spread of Mexican elements of population, may be traced as far as the beautiful Lake Nicaragua. If we follow the indications of the flora and fauna, South America begins with the mountain ranges of Costa Rica; and thus far also extend the ethnological relations which go north from Colombia over the Isthmus of Panama. This is proved by the languages and the civilization of the remains of the native population; and the same lesson, as far as our investigations have carried us, is taught by the archeological material. A limited region, including the old settlements on the slopes of the volcano of Irazú and certain groups of hills which extend down into the Atlantic lowlands, has lately been investigated in a really exemplary manner by E. V. Hartman, whose results have been published in a sumptuous work distinguished by the Swedish Academy with the Duke of Loubat's prize. Outside of this, to be sure, we still lack excavations undertaken in a scientific manner and authenticated by documents. But the whole mass of material—the eagles worn on the breast which struck Columbus and his companions, the gold ornaments found, the form of the vessels, the frequently repeated lizard and toad *motif*—prove that a similar civilization prevailed on both sides of the Isthmus of Panama, however widely the tribes were separated in language, and from whatever different points they migrated to the valleys, hills, and forests of this region. A special place belongs to the plateau of Bogotá, which marks the centre of a distinct region of civilization, the land of El Dorado, the cacique of Guatavita, who, covered with gold-dust, went out on a raft to the middle of the lagoon, and there, plunging beneath the waters, offered his costly decorations in sacrifice to the

gods. It is an interesting archeological fact that an image of this cacique and his attendants, executed in gold, has actually been found in the lagoon of Siecha. Other sites of ancient worship are still buried in the primeval forests, such as the great monuments of San Augustin near the head-waters, of the Rio Magdalena, from which Alphons Stübel has brought us drawings.

To the south of Popayan a new world opens before us, —the kingdom of the Incas, in which a number of the most diverse elements, tribes of totally different origin and various development, were fused into an external unity. Peru—especially the seaboard region—is the paradise of archeologists. On the whole coast, extending over thirty degrees of latitude, from Tumbez to the Rio Maule, not a drop of rain falls the whole year through. The sandy soil is fertilized by rivers which, rising in the snow of the ranges lying just back of the coast, bring down in their long and tortuous course a mass of particles dissolved or suspended, and are carefully conducted by the hand of man over fields, gardens, and plantations. Along these rivers and canals populous cities and towns long ago arose, whose inhabitants were well trained in the arts of both peace and war. The dry sand has preserved their dead, wrapped in mummy-coverings, with their property, their clothes and ornaments, their weapons and utensils. The colors of their garments, the flesh still clinging to the bones, the metal and wood of the utensils, the food and amulets which were buried with them, are as perfect to-day as the mummies of ancient Egypt. Many thousands of drinking-flasks, jugs, and other vessels of clay have come to light from these graves. Upon them are depicted the most various ornaments, men, gods, beasts, whole battle-scenes, judicial processes, death-dances, and banquets. Unfortunately old Peru had no Sahagun, to collect with equal diligence and intelligence the primitive

traditions of the aborigines. The *Exstirpacion de las Idolatrias* of Padre Arriaga offers us but a poor compensation. We lack the picture-manuscripts and the expositions of learned men, so that we stand face to face with this mass of phenomena almost without comprehension. All we can do for the present is to register the collected material and to seek analogies—for which not only the objects heaped up in the museums, but also the splendid publications of Reiss and Stübel and Professor Arthur Bässler give opportunity enough. One thing emerges clearly from such a survey as has been possible,—the difference between the Indians of the highlands and those of the coast, and between the civilizations of the two, as well as the distinct artistic style of the monuments and all kinds of antiquities found on the plateau of Lake Titicaca. There, at Puno and at Tiahuanaco, this difference is accompanied by a difference in language; but it may be traced far beyond the linguistic diversity, down to the coast, where Ica and Arica have long been known as places where antiquities of a distinct type were to be found. The sequence in time of the various civilizations may some day be determined with more or less certainty by such careful excavations as Max Uhle has now, for a number of years, been carrying on in Pachacamak; and no doubt it will be possible to deduce from the archeological material as yet unclassified an overlapping and fusion of indigenous civilizations with forms whose origin points to the highlands and the conquering Incas. This Inca influence may be traced plainly beyond the boundaries of their empire, by way of Ecuador towards the north, southward across the Rio Maule into Chile, and on the other side of the Cordilleras into the nearest parts of Argentina, the districts of Salta and Catamarca, where with the Spaniards the speech of the Incas, the Khechua, found its way.

But in another way the old Inca Empire was a point of departure. When Karl von den Steinen pressed on in 1883 from Cuyabá to the sources of the Xingú, he found there, to his surprise, a number of tribes similar in conditions of civilization, though differing in language, who were still living in the Stone Age, and to whom the knowledge of white men had never penetrated. The objects they used, *beixu*-turners, whirring-boards, dance-masks, and other things he found here partly painted with geometrical ornaments, for which, in a way which seemed striking to him, objects with a definite non-geometrical figure were almost always named as prototypes. He was convinced that here he saw before him in its definite results the process of the evolution of a so-called geometrical *motif* out of a definite animal, human, or other figure which Hjalmar Stolpe demonstrated for certain regions in the South Seas; and his intelligent discussion of this question has proved extraordinarily stimulating in the most various directions. In the meantime, with the extension of these investigations, it became evident that, *e. g.*, the same triangle which the Bakairí called *ulúri* (a woman's garment) was explained by other tribes as a fish's tooth. Von den Steinen himself felt compelled in consequence to revise the views he had hitherto held. He now considers that a whole class of so-called geometrical ornaments arose out of textile patterns, but, when they were transferred from plaiting or weaving on to other materials and executed in engraving or painting, acquired an independent life of their own and ended by drawing into themselves a whole series of the most varied figure-meanings, according to what appealed to the artist or was suggested to him, and with no essential relation to the original geometrical patterns. Now the old Peruvian art of the different centres is simply full of such ornamental types taken from textile art. These, together

with the figure-types which came to be used in textile work, seem to have found their way among the uncivilized tribes also, and to have furnished the suggestions for the decorations which we now meet with among tribes of the far interior of Brazil in the most varied forms, there to be interpreted and reinterpreted in sometimes extremely remarkable ways. To follow these migrations is a very attractive task, and offers another case in which archeology and descriptive ethnology must support and supplement each other.

The wide region of Argentina, the valleys lying below the Cordilleras, the Pampas, and Patagonia, formerly supported a number of half-civilized tribes, which have now dwindled to insignificant remnants or been absorbed into the Spanish-Indian mixed race. Through the labors of Argentinian scholars a mass of material has been brought to light, whose working-out has only just begun. Where the reports of the conquerors and missionaries give us scarcely more than the name of a tribe, we have now extensive dwelling-sites, including entire mountain-sides, fortifications, and burial-places. A large number of clay vessels have been found there, many of them of considerable size; stone or metal implements, and, in the tombs, even objects made of perishable material,—wooden bows, arrows, gourds with patterns burnt into them, and bundles of cords, or llama-halters, with the hoofs of llamas tied up in them, to designate, it would seem (on the principle of *pars pro toto*), the herds of llamas which the dead man possessed, or was to possess in the other world.

Whether here, as some have contended, the presence of men in a very remote geological epoch can be demonstrated is a question which as yet should not be rashly answered. Even in North America it has not yet been possible to prove beyond a doubt the coexistence of man with the great mammals which are now either extinct or vanished from Amer-

ican soil, or to push back the antiquity of human habitation as far as the time when the glaciers of the north stretched down to the Delaware and the Ohio. The problem cannot be solved alone by archeology, but needs the coöperation of geology; though it is a noteworthy fact that it is precisely the geologists who have answered this question in the affirmative. Whatever discussions may still arise, it is quite to be expected that, next to archeology, which occupies itself with tribes that come down into historical times, an important place will be filled by the branch of science which concerns itself strictly with prehistoric ages in America, as that which is capable of demonstrating the existence of man in the geological era.

American archeology in general is on firmer ground. It will not, however, be unprofitable for us, while we are reviewing what has been accomplished, to seek to show how this science has been and how it ought to be pursued. Archeology, which forms only a part of anthropology, is an empirical science, and ought never to forget this character. This it has often done in the past; preconceived opinions have been allowed to influence conclusions, and have accounted for the frequently unsatisfactory character of the latter. We all know that the study of antiquity has a special interest for many men just because it *is* the study of antiquity, and that the interest grows in proportion as one is able to ascribe a greater age to the things which form the subject of study. We also know that men are naturally inclined to consider as obvious a common single cause for similar or related phenomena, and to presuppose this even where no grounds exist to support such a theory. These two tendencies have for a long time worked a great deal of harm to American archeology. Instead of working on the material facts at hand, people have exhausted their energies in theorizing as to how this continent was settled and

whence it received its civilization, and in violent efforts to connect the civilizations which have arisen here with those of the Old World. In whatever part of the continent ancient remains have been found which offered no explanation on their face, they have assumed the presence of ancient races which have long ago vanished or migrated to other parts of the world; and when the objects discovered displayed a relatively high state of development, they have been ready, without more ado, to assert positively a connection with the known tribes of advanced civilization. In this way they have found traces of the Aztecs in the Casas Grandes of Arizona, in the cliff-dwellings, and in the mounds; and they have conducted the Toltecs, the legendary representatives of a high civilization in Mexico, from the valley of the Mississippi into that country, and thence along the line of the Andes into Peru. Luckily we have now got beyond that sort of thing. What, however, we have not yet reached, and what we should earnestly strive for, is to establish empirically what the earlier students attempted to develop on the basis of theories which they took to be well-founded,—not only the existence on the continent of various civilizations, but their order succession, and the influences to which they were progressively subjected. This has not yet been achieved, even for the two regions which have been most thoroughly investigated, the Mexican and the Central American. The great question, which of the two leading civilized races, the Maya and the Mexican, is responsible for the beginning of this civilization, or whether they both raised themselves on the shoulders of a third, is as yet unsettled. But the mutual influence of Maya and Mexicans is beyond question, and assumes a greater importance the further we penetrate into the essential nature of these civilizations, and the more we learn of their different sides and their points of divergence.

The question remains to be discussed how the archeological picture which the American continent offers has shown itself or can be made of service to the general science of all mankind, which we Germans usually call ethnology, while its followers here prefer the name anthropology. Archeology as such is only a branch of descriptive ethnography. I have tried in this brief sketch to show how our knowledge of the continent has been augmented in recent years through the labors of the archeologist. To give even a summary account of how at the same time American ethnography has gained both in extension and in depth would take hours, and is not my business. It is sufficient for me, in order to show what significant impulses have proceeded from both the archeology and the ethnography of America, to recall to you that the whole modern development of primitive sociology took its real beginning from the investigations of Lewis H. Morgan into the tribal constitution of the Iroquois, and that in the most recent researches into the philosophy of religion the old Mexican belief is beginning to play an increasingly important part. American archeology and ethnography are also of the greatest importance to general ethnology. So far as it has been possible to study the old remains and the old traditions, so far as philology gives us material for definite conclusions, so far as the comparison of art-forms has been used as a basis for still further-reaching conclusions, nowhere as yet has the often-repeated assertion that the development of the tribes on this continent was the result of influences coming either eastward or westward from what we call the Old World found any support. On the contrary, the researches of the Jesup expedition have almost conclusively proved that in the northwest there took place an overflow of American civilization, a spread of American elements of population, to the Asiatic side of the Behring Sea. For

that science, also, which tries to search out the mysteries of the laws which have governed the human mind in its development from its obscure beginnings, the observations which we have made or are in a position to make on American soil will be of greater importance than those made in any other part of the world. For the observations made here have all the advantages of pure experiment. That is the special privilege of American studies, and the special interest which attaches to them. To provide the material for that comprehensive science, the study of the human race as a whole is thus not only the real and greatest task of American archeology, but also its most rewarding. It will be a great joy to me if the conviction of this shall spread in ever wider circles, and bring to American archeology the new laborers of which it still has such pressing need.

ETHNOLOGY: ITS SCOPE AND PROBLEMS

BY ALFRED CORT HADDON

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PERHAPS there are few branches of knowledge in which it is so difficult to define its subject-matter as is the case with anthropology. The comparative newness of the study and the lack of uniformity in terminology among those who prosecute it are perhaps mainly responsible for this indefiniteness; further, the inherent complexity of the phenomena that are studied has to be taken into account. Precision of nomenclature is more difficult in the biological field than in inorganic nature, and the more complex the life the harder the task becomes. Thus it transpires that we who study the actions and thoughts of various races of men and their social groupings are sometimes at a loss to know how to name our studies with precision or to define their limits. I have had the honor of being invited to address this Congress on Ethnology, but as no information was given as to what the organizers of the Congress understood by that term, I feel it incumbent upon me to state as briefly as may be what I believe ethnology to be.

Anthropology, which is the Science of Man, clearly falls into two main divisions,—the one which deals with the

natural man (ἄνθρωπος or *homo*), the other which is concerned with man in relation to his fellows, or, in other words, with the social man (ἔθνος or *socius*).

The first group of anthropological studies includes such subjects as the comparative anatomy (somatology), physiology, psychology, development, paleontology, classification, and the distribution of the varieties of man. It was proposed by Dr. Brinton to include all these and other subjects under the term "somatology," and this classification has been adopted by the organizers of this Congress; but it appears to many British anthropologists that "anthropography" is a preferable name, the older term "physical anthropology" being somewhat cumbersome, and the restriction of the word "anthropology" to this group, as is so frequently done on the Continent of Europe, leaves no distinctive name for the whole subject. Systematic, or taxonomic, anthropography, that is, the classification of the varieties of man with their geographical distribution, is often spoken of as "ethnology," but this is to be deprecated, as the systematist deals with bodily as opposed to social characteristics; Dr. Brinton[1] termed this division "ethnography."

The second group of anthropological studies deals with everything that bears upon the domestic and social life of men. A description of a single group of mankind is sometimes described as ethnography, and in this sense it should be a monographic study including alike the physical and psychical characters of, and all that is made, done, and thought by, the group under consideration. Ethnology

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[1] Dr. Brinton's fly-sheet of a proposed classification of the anthropologic sciences was published in the *Proceedings* of the American Association for the Advancement of Science, 1892; I reprinted it as Appendix A in *the Study of Man*. Anthropology was divided by Dr. Brinton into (1) Somatology—Physical and Experimental Anthropology; (2) Ethnology—Historic and Analytic Anthropology; (3) Ethnography—Geographic and Descriptive Anthropology; (4) Archeology—Prehistoric and Reconstructive Anthropology.

is now becoming recognized as the term for the comparative study of groups of men, but it is by no means easy to distinguish theoretically between ethnology and sociology, for by its etymology the latter signifies the science of the social man. Some authors make ethnology a part of sociology, others consider sociology a department of ethnology, while a few regard them as convertible terms.

The simplest way out of the difficulty is frankly to admit that no hard and fast line can be drawn between the two subjects, but, indeed, this is always the case between allied sciences. Who can now define chemistry so as to separate it from physics, or delimit botany from zoölogy? Ultimately we have to recognize that our several studies of nature are merely so many "spheres of influence;" for the sake of convenience we attempt to pigeon-hole our investigations, but sooner or later the artificial barriers are broken down.

For example, perhaps very few sociologists would consider that a study of implements, boats, or houses falls within their province, but it is otherwise with the ethnologist. These objects are not regarded by him as, so to speak, merely superior claws, feet, or shells for individual men, but as the organs by which social man lives and by which he acts upon his fellows. The ethnologist rightly busies himself in part with these as he realizes that every implement of construction has a history, and he endeavors by patient inquiry to discover how and where it first arose and the influences that have modified its form or affected its ornamentation. The superiority of metal over stone, or of one kind of metal over another, or for certain purposes of the bow and arrow over the spear, of the cross-bow over the long-bow, and of guns over bows; or the social effects of a canoe or of a communal house, or those caused by hunting or agriculture are considerations that

do not concern the ethnologist alone; for the effect upon society of a superior weapon, a canoe, or of a house may be far-reaching, and all sociologists acknowledge the intimate connection that exists between occupation and social conditions.

On the other hand, the construction of a theory of the origin, growth, and destiny of humanity, or the enunciation of principles applicable to the ordering of social life are alien occupations to the ethnologist as such.

Probably the majority of ethnologists will admit that under their science may be classed those cultural activities which are broadly included under the arts, crafts, institutions, languages, opinions, and beliefs of all peoples. But here the old difficulty reappears. Where is the line to be drawn? Most sociologists appear to draw this line at civilization; they reserve to themselves the right to study the civilized states, while to the ethnologist they relegate the uncivilized communities.[1] It may be desirable to call the latter ethnical societies or ethnogenic associations, and the former demotic societies or demogenic associations;[2] but in practice it is often exceedingly difficult to determine whether a given community can be designated as civilized or uncivilized.

As a matter of fact, a distinction of this nature does obtain for practical purposes. Implicitly, rather than explicitly, the ethnologist does mainly confine his attention to the less civilized peoples or to the less cultivated classes of culture-peoples; but this is a matter of convenience, and he considers himself quite justified in making an occasional excursus into even the highest civilizations.

The difficulty of discriminating between two allied sub-

[1] Lester F. Ward, *Pure Sociology: A Treatise on the Origin and Spontaneous Development of Society*, 1903, pp. 15, 33.

[2] F. H. Giddings, *The Principles of Sociology*, 1896, pp. 157, 299; *cf.* also pp. 26, 27, 33.

jects, such as ethnology and sociology, is repeated when the field of history is considered.[1] Historians themselves are divided in opinion concerning the legitimate scope of their study; some claim it as a science,[2] others describe it as the artistic and emotional treatment of the whole past of mankind.[3] The two views, whether history is to be regarded as science or as literature, are irreconcilable only in their extremes. Historical data require to be collected, authenticated, and classified according to that method to which the term "scientific" is often applied, but to which the designation "critical" is equally applicable. The presentation, however, of historical facts should be in that lucid manner which is the essence of style, adorned, it may be, but not obscured, by those graces which may be termed literary; but, after all, these remarks apply equally to the physical or biological sciences.

Probably there is not much real difference of opinion concerning the critical treatment of historical data and their arrangement and elucidation. Much of this lies beyond the sphere of the ethnologist, but it is otherwise with political science, which, according to some authorities, is the central science around which historical facts and problems should be grouped, and which coördinates them. Professor Seeley asserted[4] that political science began with the classification of states, then proceeded to study the functioning and development of a state, and later to the mutual relations of states. It is therefore evident that the student of

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[1] "It is often asked, when should Ancient History be supposed to begin? Can a practical line be drawn? Archeology overlaps what we can strictly call History, but it goes much farther back; it revels in the 'prehistoric.' So too Anthropology, of which in its widest sense History is but a branch." W. E. Heitland, "The Teaching of Ancient History," in *Essays on the Teaching of History*, Cambridge, 1901, p. 38.

[2] J. B. Bury, *An Inaugural Lecture*, Cambridge, 1903, pp. 7, 42.

[3] G. M. Trevelyan, "The Latest View of History," *The Independent Review*, 1904, I, p. 395.

[4] J. R. Seeley, *Introduction to Political Science*, 1896, pp. 18, 361.

political science must turn to the ethnologist for data to assist him in his investigations.[1]

The science of history certainly does not cover the whole field of history; by its side, as Mr. Trevelyan has pointed out, three principal objects of history may be recognized: "to teach political wisdom; to restore our heritage in the ideals of the past and the lives of the noble dead; and to make us feel the Poetry of Time." Political science should teach political wisdom, and history through literature has for one of its tasks the education of the emotions.

It has been stated by Professors Langlois and Seignobos that: "The historian works with documents..every thought and every action that has left no visible traces, or none but what have since disappeared, is lost for history; is as though it had never been. For want of documents the history of immense periods in the past of humanity is destined to remain forever unknown. For there is no substitute for documents; no documents, no history."[2]

The philosophical historian understands by history something broader and deeper than documentary history; he does not confine his conception of history to the social and political interrelations of certain European countries, or "periods,"[3] but regards in his purview all conditions, ages,

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[1] As Oscar Browning states, "It appeals at once to the statesman and to the antiquarian; it is equally interesting to the politician, to the student of the most ancient races, and to the explorer of existing rudimentary societies. It is a great thing to have discovered that this is the best clue to the maze of annalistic facts. The merit of this discovery belongs justly to Professor Seeley and to Professor Freeman." *The Cambridge Review*, 1885, VI, p. 178, and pamphlet on *The Proposed New Historical Tripos*, 1897, p. 15.

[2] C. V. Langlois and C. Seignobos, *Introduction to the Study of History*, 1898, p. 17.

[3] As J. R. Tanner points out: "What is philosophically desirable is not always practically possible, and though the historian can sometimes afford to be a philosopher, the teacher of history must be a man of business. Experience shows that as a matter of business subdivision is essential." "The teaching of Constitutional History," in *Essays on the Teaching of History*, 1901, p. 51. My remarks do not apply to those who for educational reasons or for purposes of research are obliged to restrict themselves to limited periods, but to those who speak as if this method was, to say the least of it, the most important part of history.

TYPES OF INDIANS

The admirable photogravure herewith is a photographic representation of the most prominent Indian tribes of the Southwest and Northwest, which include the Apache, Zuni, Pueblo, Cocopas, Moqui, Navajo, Sioux, Arrapaho and Chippewa. In this gathering of tribes at a recent Anthropological and Ethnological exhibit the semi-civilized were brought into comparison with the least developed, distinction between the classes being readily observed by the difference in dress. The intractable Indian refuses to discard his blanket, his beads and his feathers, while those amenable to education and improvement adopt the white man's dress, and become agriculturists, artisans and sometimes common laborers.

and climes, or, in other words, he studies universal history.[1] Hence it becomes necessary to throw every possible light upon those shadowy beginnings of the culture-nations when all knowledge was stored in human brain-cells. Tradition has handed down to history only the most fragmentary traces of the unwritten lore, and these are totally inadequate to supply the documentary historian with sufficient data to complete his narrative. Here the ethnologist comes to the aid of the baffled historian and supplies him with accounts of existing peoples who have dallied along the road that leads to civilization, and amongst these laggards there can be selected parallels to the various phases through which various civilizations have passed. As geography and ethnology are the open pages of those portions of earth-history, of which stratigraphy and archeology are the pages already turned down, so the history of the earth (geology) and the history of man are consecutive narratives that incorporate the past and the present.

For the sake of convenience archeology is generally regarded as a subject of equal rank with anthropography and ethnology, but it bears the same relation to ethnology that paleontology does to biology. The finds are fossil implements, shards, house-sites, and the like, but, as the paleontologist must be a zoölogist if his dry bones are to be vivified, so must the archeologist turn to ethnology for existing parallels or for suggestions as to the probable use or meaning of particular objects; hence the distinction between the finds of the archeologist and the collections of

[1] "What do we mean by a Universal History? Briefly: a History which shall (first) include all the races and tribes of man within its scope, and (secondly) shall bring all these races and tribes into a connection with one another such as to display their annals as an organic whole. Universal History has to deal not only with the great nations, but also with the small nations; not only with the civilized, but also with the barbarous or savage peoples; not only with the times of movement and progress, but also with the times of silence and apparent stagnation. Every fraction of humanity has contributed something to the common stock, and has lived and labored not for itself only, but for others also through the influence which it has perforce exercised on its neighbors." James Bryce, "Introductory Essay," in *The World's History: A Survey of Man's Record.* Edited by H. F. Helmolt, 1901, I, p. xxi.

the ethnologist is not one of degree but merely a question of chronology.

It is convenient to speak of the less advanced people in civilized communities as the "folk," and folklore is what the folk think and do, and its essential character is that it is traditional. Practices were observed and copied, and in this way there has accumulated a vast amount of traditional thought and usage that has been handed down from the childhood of man, and is still being transmitted. Although the bulk of folklore is current among the less educated classes, there is a good deal persisting among the so-called higher classes, and new vagaries are constantly appearing.[1]

Folklore bears the same relation to the study of comparative custom and belief that archeology does to ethnology and history, but with this difference, that the main data of archeology are tangible objects, whereas those of folklore are intangible: folklore may thus be described as psychical archeology. To take a zoölogical parallel, archeology and folklore bear the same relation to ethnology as paleontology bears to zoölogy, for the latter includes the study of the survivals of earlier types as well as the more differentiated forms that constitute the enormous majority of existing animals.

The historian, also, whether he deals with the history of ancient civilizations, or even with that of early Europe, is dependent upon the archeologist, not only for the explanation of his documentary accounts, but for the accumulation of fresh data. The classical scholar, the Egyptologist,

[1] Two examples will suffice: "A lady living within the shadow of the walls of Harvard University maintains that carbons from arc lamps are a sure preventive of neuralgia." Frank Russell, President's Address, American Folk-Lore Society, *Science*, 1902, p. 569. "In many motor-cars is suspended a perforated stone, usually a sea-rolled flint, with a natural bore; this stone is supposed to act as a protective amulet. It is supposed to confer safety on the fastest traveling motor-car, and there is many a speedy driver who in his heart ascribes his immunity from accidents to the strange power of the perforated pebble." *Daily Chronicle* (London), March 14, 1903.

the Assyriologist, and others who interest themselves in the resurrection of past action and belief fully recognize that the remains unearthed by the spade are of as much value to their studies as are written documents. No better example of this can be found than in the monumental translation and commentary of *Pausanias's Description of Greece* by Dr. J. G. Frazer, in which the text of the somewhat common-place Greek sight-seer is illumined with a great wealth of archeological lore, and the strange incidents recorded by the ancient writer are matched by suggestive parallels from European folklore or from the vast storehouse of Dr. Frazer's ethnological erudition.

"What a 'cabinet of specimens' is to a professor of mineralogy, what an 'anatomical museum' is to a professor of anatomy, the tribes of the South Sea Islands may be to the professor of history, whether he teach from a chair or by means of a printed book. If only a small fraction of the time and intellectual effort devoted to the investigation of obscure points in the history of early Egypt, early Mesopotamia, early Greece, or early Italy—or indeed of early Britain—had been added to the little which has been devoted to South Sea Island investigations of a similar kind, those points would have been cleared up more easily." So writes Vice-Admiral Sir Cyprian Bridge[1] and he proceeds to adduce examples, culled from his own wide experience in various parts of Oceania, of present-day illustrations of events that happened before the walls of Ilios, or parallels in custom between the Micronesians and the ancient Germans. In my own small experience[2] I have passed in a week or two from the stone-age savagery of the Papuans to the barbarism of Borneo, which recalls in many respects the stage

[1] Cyprian A. G. Bridge, Introduction to *The Caroline Islands*, by F. W. Christian, 1899, p. 6.

[2] *Head-Hunters: Black, White and Brown*, 1901.

of culture at which Europe had arrived at the time when iron was replacing bronze.

It has often been noted that the history of human culture is largely the history of the domination of nature by man; at first man was simply a creature of circumstances like any other animal, then gradually he commenced his work of subduing the earth. The donning of clothes and the discovery of fire rendered man less dependent upon purely geographical conditions. As the Right Honorable James Bryce says: "We need not pursue his upward course, at every stage of which he finds himself better and still better able to escape from the thralldom of nature, and to turn to account the forces which she puts at his disposal. But although he becomes more and more independent, more and more master not himself, but of her, he is none the less always for many purposes the creature of the conditions with which she surrounds him....In the earlier stages he lies helpless before her, and must take what she chooses to bestow....but in the later stages of his progress he has, by accumulating a store of knowledge, and by the development of his intelligence, energy, and self-confidence, raised himself out of his old difficulties....As respects all the primary needs of his life, he has so subjected nature to himself that he can make his life what he will..Thus his relation to nature is changed. It was that of a servant, or indeed that of a beggar, needing the bounty of a sovereign. It is now that of a master needing the labor of a servant, a servant infinitely stronger than the master, but absolutely obedient to the master, so long as the master uses the proper spell."[1] The elucidation of this evolution of culture has been the work of ethnology.

The interrelations between man and his environment are manifest in multifold ways, since, as is evident to all, the

[1] J. Bryce, *loc. cit.*, pp. xxvi, xxvii.

physical conditions of a country, including the climate, the vegetation, and the indigenous animals, affect the life of the human inhabitants of that country. The main occupation of a people reacts upon its social life; thus, within certain limits, the character of the organization of the family, the nature of larger social groupings, and the regulation of public life are products of the environment. Not less has the environment impressed itself upon the arts of life and as much also upon the complex activities that may be placed under the general term of religion. The religious conceptions of a hunter must necessarily differ from those of a shepherd or of an agriculturist, and the religion of desert-dwellers must find a different expression from that of jungle-folk.

Primitive men simply gathered vegetable and animal food, later they became definite hunters, and hunting-folk are still the least advanced of any people; they are what are termed "savages."

Under stress of circumstances certain people devoted themselves to agriculture, and, according to the local conditions, cultivated certain plants, each of which definitely reacted on the social life of the agriculturists. Other peoples became herders instead of hunters of animals, and they necessarily were at first very mobile. Fishing-populations generally form characteristic communities that gain command of the seaboard.

These four types of societies, with their several modifications, occurred in Europe in prehistoric times as well as in the early historic period, and the various ways in which they reacted upon one another were very marked.

The agricultural peoples gradually brought the plains and forest lands into cultivation. As they acquired wealth, they were despoiled by the herdsmen, who, being horsemen, could readily overrun the country and defy pursuit. The agri-

culturists could not well defend themselves, being unwarlike and footmen; but it depended upon the degree of the social evolution of the herdsmen how far the results of this conquest were lasting. Attila, Genghiz Khan, and Tamerlane neither organized nor administered the conquered populations; they passed like a hurricane, and scarcely left more lasting traces of their progress. The Turks are still only encamped in Europe, they are simply superimposed upon the peoples they dominate, and there is practically no assimilation; similarly the Manchus are aliens in China. On the other hand, the early Teutonic horsemen forced themselves upon the agriculturists of Gaul and permanently overlorded them; and the highly organized, cultured, religious enthusiasts who were trained in the Sahara established themselves in Spain for centuries.

The Phœnician, and later the Greek, fishermen developed into more or less piratical merchants in the Mediterranean, as have the Malays in the East Indian Archipelago. In the North Sea the Scandinavian fishermen raided Ireland for gold and treasure, or settled in Britain and Northern Gaul, their leaders becoming aristocratic landowners and rulers of the people. A similar history was repeated in Slavia by the Scandinavian Varangians; thus it was that different branches of the same race gave their names respectively to England, France, and Russia.

The foresters and the miners, as such, have played only a passive part in the history of Europe.

Speaking broadly, we may say that human societies are molded by physical environment, conditioned by biologic environment, and stimulated by ethnic environment.

As human societies become more complicated, their interrelations grow more complex; but in one form or another the struggle of classes continues. For the elucidation of the earlier phases of these and similar social or historical

occurrences recourse must be had to the ethnologist, for it is his province to record the social constitution and the social kinetics of existing backward peoples, and it is only by these comparative studies that light can be thrown upon the past history of nations.

Have we, however, a right to restore the past by an appeal to the present? The labors of such students as Andrée, Bastian, Durkheim, Frazer, Gerland, Hartland, Post, Ratzel, Robertson Smith, Steinmetz, Tylor, and others have, in the words of Dr. Brinton, proved there is something universal in humanity. "Its demonstration is the last and greatest conquest of ethnology, and it is so complete as to be bewildering. It was brought about by the careful study of what are called 'ethnographical parallels.'"[1] Dr. Post does not hesitate to say: "Such results leave no room for doubt that the psychical faculties of the individual, as soon as they reach outward expression, fall under the control of natural laws as fixed as those of inorganic nature."[2] "As the endless variety of arts and events in the culture-history of different tribes in different places, or of the same tribe at different epochs, illustrates the variables in anthropologic science, so," continues Dr. Brinton, "these independent parallelisms prove beyond cavil the ever-present constant in the problem, to-wit, the one and unvarying psychical nature of man, guided by the same reason, swept by the same storms of passion and emotion, directed by the same will towards the same goals, availing itself of the same means when they are within reach, finding its pleasaure in the same actions, lulling its fears with the same sedatives."[1]

On the other hand, absolutely necessary and invaluable as is the comparative method, it should not be abused.

[1] D. G. Brinton, "The Aims of Anthropology," *Proceedings*, American Association for the Advancement of Science, 1895, XLIV.

[2] A. H. Post, "Ethnologische Gedanken," *Globus*, LIX, no. 19.

Things which are apparently similar need not necessarily be the same, for, as the biologists have long taught, analogy and homology are two very different things. Thus it is conceivable that two customs or simple ceremonies may resemble one another so closely as to appear quite similar, but, however convergent their outward forms may be, if the motive for their performance is different we must not regard them as identical. The masters of the comparative method are fully alive to this danger, but it is one into which the enthusiastic beginner is apt to fall, and all the more readily as it is very difficult to ascertain the true motives for a given custom, and, too often, the performance itself has been very imperfectly recorded.

So far I have considered what may be regarded as those aspects of ethnology which add to the sum of human knowledge; but we may safely urge that part of the business of ethnology is to provide data which can be utilized by the practical politician, and possibly at no very distant period this fact will be clearly recognized by those who aspire to a career in affairs, as well as by the faculties of those institutions where men are trained for public life. But, I would again assert, the practical application of ethnological data to current statecraft is not the province of the ethnologist.

"To the aspirant for honors in the diplomatic service," says Dr. Frank Russell,[1] "anthropology offers an admirable training. He learns the significance of the racial factor in national welfare; the measure and condition of progress; the principles of ethnologic jurisprudence; and also the characteristics of the particular people among whom his duties lead him.

"For the legislator, anthropology must become a neces-

[1] F. Russell, "Know, then, thyself," *Journal of American Folk-Lore Society*, 1902; *Science*, 1902, p. 570.

sary preparation. America has problems whose solution calls for the widest knowledge of races and cultures. Such knowledge, free from political bias and hereditary prejudice, can best be gained by the study of the science of man.

"Anthropology prepares the lawmaker and the jurist for the task of coping with crime. Criminal anthropology has explained the character and causes of criminality and degeneracy, and led to revolutionary changes in the methods of crime prevention."

As Dr. Brinton has pointed out, the branch of anthropology, which has for its field the investigation of the general mental traits of various peoples, for which the Germans have proposed the name Characterology (*Karacterologie*), "is that which offers a positive basis for legislation, politics, and education, as applied to a given ethnic group; and it is only through its careful study and application that the best results of these can be attained, and not by the indiscriminate enforcement of general prescriptions, as has hitherto been the custom of governments."[1] Most civilized nations have living within their borders groups of people who differ in race, language, custom, and religion from the bulk of the population. The arbitrary politician seeks to force all such into his Procrustean bed of wont and faith, as, for example, Russia is attempting to do in her Baltic provinces and in Finland; but surely there is a more excellent way.

Perhaps still more are sympathy and knowledge required by those who have to deal with native races. There can be no question but that a full knowledge of local conditions and a sympathetic treatment of native prejudices would materially lighten the burden of government by preventing many misunderstandings, and thus, by securing greater efficiency, would make for economy.

[1] D. G. Brinton, *loc. cit.*

To look at the matter from the lowest point of view, even a slight frontier trouble means a direct expenditure for the local executive and a stagnation of trade. Commerce is, as it were, a sensitive barometer that fluctuates with every small variation of pressure in the political firmament and the pecuniary loss to a country is not to be measured by the actual expenditure consequent upon a trouble with natives, so much as by the indirect loss to the community at large; this can rarely be estimated, but it is none the less real.

"To the man of affairs," writes Professor W. Cunningham,[1] "economic history may prove of interest from quite another reason—by furnishing a clue to unfamiliar habits and practice in the present day. The expansion of Western civilization has brought Europeans and Americans into the closest contact with many barbarous and half-civilized peoples, whose usages and habits are strange to us. For purposes of trade it is convenient to understand their methods of dealing; while the administrator who rules over them cannot easily see how the incidence of taxation will be distributed in their communities or what are the possibilities of social oppression against which it is necessary to guard. Some of the most regrettable blunders of the English Government in India have been due to an inability to understand the working of native institutions. A careful study of the past of our own race, or of the earlier habits of other peoples when natural economy still reigned, would at least have suggested a point of view from which the practical problems in India might be more wisely looked at. By means of analogies drawn from the past we may come to understand the advantage, under certain circumstances, of fiscal methods that seem to be cumbrous, and the danger

[1] W. Cunningham, "The Teaching of Economic History," in *Essays in the Teaching of History*, 1901, p. 46; *cf.* also W. F. Flinders Petrie, *Report* of British Association for the Advancement of Science, 1875, pp. 820-824.

of introducing modern improvements in a polity that is not prepared to assimilate them."

There are higher grounds than those of mere expediency for the carrying-out of this policy, and there ought to be no need to insist upon this point of view. Fortunately there are not lacking examples of backward peoples being helped by the wise leadership of Europeans. I may instance the cases of British New Guinea,[1] Torres Straits,[2] and especially that of Sarawak,[3] where many varied tribes are helped under the "mild despotism" of His Highness Rajah Sir Charles Brooke, to govern themselves; the central idea of the Government being the benefit of the natives and the gradual betterment of their condition by natural growth from within, and this is successfully accomplished by a sympathetic knowledge of the people.

Other examples of wise administration of native states by Europeans could easily have been adduced, but I preferred to limit my remarks to those regions that have come under my personal observations. May I be permitted to utter one word of warning? For social evolution to be efficient and permanent it should be the result of a response to needs felt by the people themselves, and consequently such progress is usually very slow, for even the recent rapid advance of Japan is the result of long years of discipline and training, without which she could not have seized her opportunities and improved upon her teachers. The Western world is passing through a phase of "hustle" which also manifests itself in a tendency unduly to accelerate the cultural evolution of backward peoples.

We have now to consider the problems of ethnology and the direction the development of the science should take in

[1] W. Macgregor, *British New Guinea: Country and People*, 1897, pp. 41, 97.

[2] *Reports of the Cambridge Anthropological Expedition to Torres Straits*, 1904, v, p. 264.

[3] *Head-Hunters: Black, White, and Brown*, 1901, p.

the immediate future. From almost whatever point of view we regard history, we find that the comparative studies of the ethnologist afford explanations of historical phenomena which the historical records are usually too imperfect to elucidate with sufficient detail. As a matter of fact it is hardly going too far to suggest that in the existing state of our knowledge the present explains the past more than the past explains the present. Hence the pressing need for complete ethnological investigations before the data are lost.

I may be wrong, but it appears to me that there are few special problems in ethnology that require elucidation to the exclusion of others. Some departments of inquiry are of greater importance in the cultural history of man than are others, but owing to the far-spreading interactions of human ideas and deeds, it is often very difficult to pronounce with any degree of certitude that a particular branch of inquiry is of such relative unimportance that it can safely be neglected, or even merely postponed.

It may not be unprofitable, however, to glance at the five groups of subjects,[1] which, as I have previously stated, are regarded by certain ethnologists as the main divisions of their science, and to indicate some of the lines that require investigation.

Esthetology embraces the study of the activities of mankind connected with more or less spontaneous sensations of pleasurable character. It has been said that among primitive peoples these activities appeal chiefly to the senses, and among the more advanced peoples they appeal largely to the emotions and to the purely intellectual faculties.

[1] These five fields of ethnological study were formally stated by J. W. Powell in the Introduction to the *Sixteenth Annual Report of the Bureau of American Ethnology*, 1894-95 (1897), when the term "sophiology" was introduced (p. xviii). They were amplified by WJ McGee in an address on "The Science of Humanity" delivered before Section H of the American Association for the Advancement of Science, Detroit, August 9, 1897, (*cf. American Anthropologist*, 1897, p. 241; *Science*, Sept. 17, 1897, p. 413, and *Annual Report*, American Association for the Advancement of Science, vol. LXVI, p. 293; also *cf. American Anthropologist* (N. S.) I, 1899, p. 401). Major Powell elaborated his ideas in a series of essays published in the *American Anthropologist* (N. S.) I, 1899, pp. 1, 319, 475; II, p. 603; III, p. 51.

Of late years considerable attention has been paid to tne subject of decorative art, and there are few subjects studied by ethnologists which have such a wide range of interest as has this. It is being abundantly proved that, speaking generally, the majority of designs and patterns have a definite significance, and thus they are not merely pleasing and meaningless dispositions of form, or color, as so often are those of modern decorative artists. There is only one possible method of discovering the real meaning of any particular design, and that is by inquiry in the field, and even then it is not always possible to get all the information that is desired, for, as has been shown by von den Steinen,[1] Kroeber,[2] Boas,[3] and others, the same simple design may have different meanings, and often it is the original designer alone who knows precisely what was the idea that a particular decoration was intended to record; at all events, this is the case with the Plains Indians. How mistaken, therefore, is it for students to rely solely upon museum material, as still is too much done!

What do we really know about the music of most of the backward peoples?

The amusements of peoples deserve more careful study, but this is becoming increasingly difficult, owing to the recent rapid diffusion of alien culture among native races. A comparative study of games is being made by Culin, based mainly upon the collection in the Free Museum of Science and Art in Philadelphia; but here also much work must be done in the field before trustworthy results can be obtained.

Whatever department of esthetology is studied, not

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[1] K. von den Steinen, *Unter den Naturvölkern Zentral-Brasiliens,* 1894, pp. 258-270.

[2] A. L. Kroeber, *American Anthropologist,* 1901, III, p. 308; *Bulletin,* American Museum of Natural History, 1900, XIII, p. 69; 1902, XVIII, p. 1.

[3] F. Boas, *Popular Science Monthly,* Oct., 1903; Supplement to Am. Museum Journal, IV, no. 3 (Guide Leaflet to Am. Mus. Nat. Hist. no. 15).

merely must the objects or facts be collected, and their significance ascertained, but ever must one remember that they all have a psychological significance, and this too must be studied in the field; a highly suggestive presentation of this aspect will be found in Hirn's *Origins of Art*.

Technology. The study of what man makes and how he makes it, is one that has appealed to many workers. Our museums are full of weapons and utensils, but in numbers of instances our knowledge about them is very imperfect. The localities from which objects are supposed to come are frequently vague and occasionally incorrect; the exact materials of which they are made, and the method in which they are made are rarely recorded. There are extremely few sets of photographs that illustrate all the stages in the making of an object; this latter is an important point, as the manufacture of primitive implements is fast disappearing. For such purposes the cinematograph might very well be employed by the ethnologist in addition to ordinary photography.

Sociology. The progress of all cultural peoples has depended primarily upon social habits, and the tracing of this evolution is one of the most important tasks that the ethnologist has to accomplish. In taking a general survey of the literature of comparative sociology, one is at first sight inclined to think that a fairly adequate amount of information has been collected; but when one begins to analyze the material a very different impression is arrived at. The statements are found to be too general and to lack precision in detail. Among less advanced peoples the communities are usually rigidly organized, and definite duties are allocated to certain individuals according to their position in the community at large or according to their kinship. In order to gain a thorough knowledge of the construction of any society, it is essential that these several duties should

be clearly recorded, and exact information should be given concerning the individuals by whom they are performed. It is precisely in such details that most accounts hopelessly break down. As the social structure of many peoples has been shattered by contact with Europeans it is of the greatest importance that an effort should be made to recover this class of information; in many cases it is probably already too late, but in others it is possible that something may yet be saved. As a matter of fact, a very large proportion of the earlier observations on the sociology of native races requires to be confirmed and amplified.

Philology, or *Linguistics*, deals not so much with languages as with language, its origin, nature, and laws, and in addition to the spoken language the ethnologist studies gesture- and sign-language, as well as pictographic, symbolic, ideographic, and phonetic writing.

An interesting field for research will be found in the evolution of literature, but even this cannot be culled from existing books, as verbatim transliterations of tales, songs, and sayings are very rare, and free renderings, and abbreviated accounts are of little value from this point of view.

Sophiology is a word invented by Major Powell to comprise the study of "inferences, conclusions, abstractions, beliefs, and all other forms of knowledge or pseudo-knowledge;" he defined it as "A science of opinions, including the activities of promulgation and acceptation." Although it is true we have a mass of material dealing with these subjects, no one can admit that it is sufficient.

Innumerable magical practices have been recorded, but even so, more information is required as to the method in which they are supposed to act. Dr. J. G. Frazer[1] regards religion as opposed in principle to magic, and holds that an

[1] J. G. Frazer, *The Golden Bough: a Study in Magic and Religion* (2d ed. 1900), I, pp. 63, 75.

age of religion has everywhere been preceded by an age of magic. Others, as Marett puts it,[1] consider that "Magic proper is all along an occult process, and as such part and parcel of the 'God-stuff' out of which religion fashions itself."

The problem of sophiology are fundamentally questions of psychology, and they require to be studied by those who have had a thorough training in that science.

The appliances and ceremonies of religion are of the highest interest, and should be described with great minuteness, and the associated myths, which are probably always later than the observances for which they are supposed to account, deserve to be written down. Of late years certain ceremonies have been described with an admirable wealth of detail and illustration by American ethnologists such as G. A. Dorsey, J. W. Fewkes, Washington Mathews, J. Mooney, and H. R. Voth; and Baldwin Spencer, F. J. Gillen, and W. Roth have done the same great service to science in Australia.

After all, ritual is but the outward form of the more important religious idea, and field-work undertaken by suitably trained observers is necessary before much advance can be made in tracing the evolution and early vagaries of this idea.

It is a matter for regret that, although a great deal is now being written on symbolism and religious art, comparatively little of it is the outcome of work in the field.

To whatever department of ethnology we turn our attention, wherever we glance over the map of the world, the fact is increasingly evident that we need more extensive and more detailed observations. The data upon which students at home have to rely are usually of the most imperfect character; this, however, is not at all to be wondered at when we

[1] R. R. Marett, "From Spell to Prayer," *Folk-Lore*, 1904, xv, p. 160.

consider the training of those who collected the information or the manner in which it was obtained. The reliable collector is as fully aware as is the helpless student of the imperfection of his record, and for this there is only one remedy,—more extensive and more thorough investigations in the field carried on by trained observers.

Travelers and residents, naturalists as well as anthropologists, continually point out that throughout the world a very rapid change is taking place among nearly all peoples. The expansion of Europe has affected the less civilized peoples in very diverse ways, and this pressure has resulted in social upheaval, the upsetting of traditional safeguards to morality, and weakening of old faiths.

Owing to the withering influence of the white man, the more primitive peoples are more or less rapidly disappearing; either they are actually dying out, as are the Australians, who are quickly following the now extinct Tasmanians, or they are becoming so modified by contact with the white man and by crossings with alien peoples who have been deported by Europeans that immediate steps are necessary to record the anthropological data that remain. Not only are the opportunities for study fast slipping away, but this process is actually fastest in those countries where the most important results are likely to be obtained. There is no exaggeration in this. The delay of each year in the investigation of primitive peoples means that so much less information is possible to be obtained.

A word of warning is not unnecessary. There is still a greater danger that travelers will make it their first endeavor to amass extensive collections, quite regardless of the fact that a sketch or a photograph of an object about which full particulars have been collected is of much greater scientific value than the possession of the object without the information. The rapid sweeping up of specimens from a locality

does great harm to ethnology. As a rule only the makers of an object can give full details respecting it, and no traveler who is here to-day and gone to-morrow can get all the requisite information; this takes time and patience. The rapid collector may get some sort of a story with his specimen, but he has no time to check the information by appeal to other natives, or to go over the details in order to see that he has secured them all and in the right order.

It is now recognized that many native objects have a deeper significance than would be suspected by the casual observer. This can only be coaxed out of the native by patient sympathy. Some information may be "rushed," but the finer flowers of the imagination, the spiritual concepts and sacred aspirations, can only be revealed to those with whom the native is in true sympathy, and, quite apart from idiosyncrasy, the time-element is a most important factor. No, the rapid collector does positive harm, as, like the unskilled excavator, he destroys the collateral evidence. He may add a unit to a collection, but its instructive value is reduced to a minimum: it is the gravestone of a lost opportunity.

A thorough scientific training is essential for satisfactory field-ethnology. It is quite a mistake to assume that practically any one can successfully undertake this class of research, for it is mainly owing to a lack of training that such a great deal of the work of the earlier observers requires to be done over again. There are numerous instances of men trained in various branches of science who have proved to be successful ethnologists, but preliminary instruction in ethnology would have saved them much time and would have considerably improved their results. We need travelers who can observe accurately and record intelligently, who have trained minds and can understand the value of evidence, who have sufficient previous knowledge to know

what to look for, and who are instructed not only in all the methods of ethnological research, but who have been warned of the pitfalls that endager the unwary. As the investigator usually has to study all the aspects of the life of the people he visits, so is it necessary for him to have a wide knowledge of arts, crafts, and sciences, otherwise he will be unable to grasp the full significance of what he sees and hears. As a matter of fact, there is practically no branch of knowledge which may not prove useful to the field-ethnologist.

So far I have spoken merely of his intellectual equipment, but there are other qualifications which should not be passed over.[1] The field-ethnologist should be an artist, or at least have the artistic temperament. Only thus will he be able to appreciate what it is in the art expression of the people he is studying that gives them pleasure and satisfaction. He should be able to recognize the artistic impulse which from our point of view is a germ rather than a realization, and thus discern what the people are striving after despite uncouth and imperfect presentation.

Finally, he should have sympathy. A great deal has been done by energy and intelligence, but the finest ethnological work can be accomplished only by that subtle quality that

[1] "There are also two personal traits which, it seems to me, are requisite to the comprehension of ethnic psychology, and therefore are desirable to both the ethnologist and the historian, the one of these is the poetic instinct.

"I fear this does not sound well from the scientific rostrum, for the prevailing notion among scientists is that the poet is a fabulist, and is therefore as far off as possible from the platform they occupy. No one, however, can really understand a people who remains outside the pale of the world of imagination in which it finds its deepest joys; and nowhere is this depicted so clearly as in its songs and by its bards. The ethnologist who has no taste for poetry may gather much that is good, but will miss the best; the historian who neglects the poetic literature of a nation turns away his eyes from the vista which would give him the farthest insight into national character.

"The other trait is more difficult to define. To apprehend what is noblest in a nation one must one's self be noble. Knowledge of facts and an unbiased judgment need to be accompanied by a certain development of personal character which enables one to be in sympathy with the finest tissue of human nature, from the fiber of which are formed heroes and martyrs, patriots and saints, enthusiasts and devotees. To appreciate these something of the same stuff must be in the mental constitution of the observer."

D. G. Brinton, *An Ethnologist's View of History*, an address before the Annual Meeting of the New Jersey Historical Society at Trenton, N. J., Jan. 28, 1896.

eludes definition. All sorts and conditions of men will open out and reveal their secrets and unveil their mysteries if approached in a spirit of *camaraderie,* but it is permitted only to the sympathetic to enter into the innermost shrine where are laid bare the hopes and fears, the ideals and aspirations, of another's soul. The rude and the rough, the cynic and the skeptic, cannot enter here.

My plea, then, is for investigators, not for mere collectors; as many of the former as possible and as few of the latter. There is not much difficulty in finding men willing and competent to undertake such investigations if funds were forthcoming. One point is worth mentioning for their further encouragement: in most branches of scientific inquiry, later investigations, owing to more minute study improved methods, or a new point of view, are apt entirely to eclipse the earlier discoveries. Now this is not the case with ethnological research in the field. The earlier the observations are, provided they are full and accurate, the more liable they are to be of greater importance than the later ones. Students continually refer to the oldest books of travel, and they will always do so. From this point of view it is evident that properly qualified investigators should set to work without delay. Every year's delay means that the work will be so much the less perfect. All who are concerned in any field of work can have the satisfaction of feeling that students of mankind in future ages will have to consult their publications, and they have the tremendous responsibility that what they write will have to be accepted as correct, as there will be no means in the future of checking it.

The work that requires to be done is of so extensive a nature that no one institution, not even one country, can hope to do more than efficiently cover a small portion of the field. It appears to me that this is one of those departments of science that require coördination. Individual action can

accomplish a good deal in restricted areas, but would not systematic coöperation be more efficacious in most cases? There are certain districts that need more immediate attention than others, and an international body should be in a better position to direct field-research towards the most profitable districts and to facilitate the work of the investigators than a private individual.

More than once[1] have I pointed out that it is well from time to time to take stock of our knowledge and of our methods of inquiry, to see whether we are working on sound lines. As the business man finds it necessary to go over his stock periodically and to balance his books, so also the scientific man, especially the biologist, should perform an analogous operation, lest perchance he finds out too late that he has been entering on a comparatively unprofitable piece of work, or has been neglecting valuable opportunities.

We can, perhaps, gain a clearer view of the question by looking at it from the standpoint of our successors. What opinion will the sociologist and the historian of a hundred, or of a thousand, years hence have of the work now being done? What is the research they would wish us to have undertaken? The question is not a difficult one to answer. They will certainly and most justly complain if we busy ourselves entirely with problems that can wait, which they can solve as well as we, while at the same time we neglect that work which we alone can do.

Our obvious and immediate duty is to save for science those data that are vanishing. This should be the watchword of the present day. It is difficult to suggest an object more worthy of liberal support than this. In sober earnestness, therefore, I appeal to all those who are interested in

[1] *Nature*, January 28, 1897, p. 305; *Popular Science Monthly*, January, 1903. p. 222.

the history and character of man, whether they be theologians, psychologists, historians, sociologists, or anthropologists, to face the fact that a later generation may employ itself in working-up the results garnered by ourselves or in studying other subjects, but to this generation, and to this alone, is appointed the task to which I have now drawn your attention.

BOOKS OF REFERENCE ON GEOLOGY AND PALEONTOLOGY

(Prepared by courtesy of Herbert P. Whitlock of the staff of the New York State Museum.)

GENERAL

GEIKIE, A., Text Book of Geology, 2 vols., London, 1904.

DANA, J. D., Manual of Geology, New York, 1895.

DE LAPPARENT, A., Traité de Géologie, 3 vols., Paris, 1900.

NEUMAYR, M., Erdgeschichte, 2 vols., Leipzig, 1895.

CHAMBERLAIN, T. C., and SALISBURY, R. D., Geology, 2 vols., New York, 1904.

BRIGHAM, A. P., Text Book of Geology, New York, 1902.

COSMICAL GEOLOGY AND GEOGNOSY

CROOL, J., Climate and Time, Edinburgh, 1885.

FISHER, O., Physics of the Earth's Crust, London, 1881.

WILLIAMS, E. H., Manual of Lithology, New York, 1895.

KEMP, J. F., Handbook of Rocks, New York, 1896.

ROSENBUSCH, H., Mikroskopische Physiographie der Mineralien und Gestein, Stuttgart, 1885-87.

DYNAMIC GEOLOGY

SUESS, E., Das Antlitz der Erde, Prague, 1883-88.

DAUBREE, A., Etudes synthétiques de Géologie Expérimentale, Paris, 1879.

DANA, J. D., Characteristics of Volcanoes, New York, 1890.
Corals and Coral Islands, New York, 1890.

JUDD, J. W., Volcanoes, New York, 1881.

HEILPRIN, A., Mont Pelée and the Tragedy of Martinique, Philadelphia, 1903.

MILNE, J., Earthquakes, New York, 1886.

MERRILL, G. P., Rocks, Rock-weathering and Soils, New York, 1897.

SHALER, N. S., Origin and Nature of Soils, U. S. Geol. Sur., 1890-91, part I.

DARWIN, CH., Coral Reefs, London, 1891.

BONNEY, T. G., Ice Work, New York, 1896.

GEIKIE, J., The Great Ice Age, New York, 1895.

KING, F. H., Principles and Conditions of the Movements of Ground Water, U. S. Geol. Sur., 1897-98, part II.

STRUCTURAL GEOLOGY

Van Hise, C. R., A Treatise on Metamorphism, U. S. Geol. Sur., Monograph 47, 1904.

Principles of North American Precambrian Geology, U. S. Geol. Sur., 1895-96, part i.

ECONOMIC GEOLOGY

Philips, J. A., and Louis H., A Treatise on Ore Deposits, London, 1896.

Kemp, J. F., Ore Deposits of the United States and Canada, New York, 1901.

Posepny, F., The Genesis of Ore Deposits, New York, 1895.

Branner, J. C., and Newsom, J. F., Syllabus of a Course of Lectures on Economic Geology, Stanford University, 1900.

Dewey, F. P., A Preliminary Descriptive Catalogue of the Systematic Collections in Economic Geology and Metallurgy in the U. S. National Museum, Smithsonian Institution, Bull. 42, 1891.

Merrill, G. P., Guide to the Study of the Collections in the Section of Applied Geology in the U. S. National Museum, Report of the U. S. Nat. Mus., 1889, Washington, 1901.

Stones for Building and Decoration, New York, 1891.

Van Hise, C. R., Bayley, W. S., and Smyth, H. L., The Marquette Iron-bearing District of Michigan, Monograph 28, U. S. Geol. Sur., Washington, 1897.

Irving, R. D., The Copper-bearing Rocks of Lake Superior, Monograph 5, U. S. Geol. Sur., Washington, 1883.

Winslow, A., Lead and Zinc Deposits of Missouri, Geol. Sur., of Missouri, vol. vii, Jefferson City, 1894.

Emmons, S. F., Geology and Mining Industry of Leadville, Monograph 12, U. S. Geol. Sur., Washington, 1886.

Hatch, F. H., and Chalmers, J. A., The Gold Mines of the Rand, London and New York, 1895.

Cross, W., and Penrose, R. A. F., Geology and Mining Industry of the Cripple Creek District, Colorado, U. S. Geol. Sur., 1894-95, part ii.

Becker, George F., Geology of the Quicksilver Deposits of the Pacific Slope, Monograph 13, U. S. Geol. Sur., Washington, 1888.

Kunz, G. F., Gems and Precious Stones of North America, New York, 1900.

Singer, von L., Beiträge zur der Petroleum Bildung, Vienna, 1893.

Peckham, S. F., Production, Technology, and Uses of Petroleum and of its Products, 10th Census, vol. x, Washington, 1884.

MERRILL, F. J. H., Salt and Gypsum Industries of New York, Bull. 11, N. Y. State Museum, Albany, 1893.

Report on the Building Stones of the United States, 10th Census, vol. x, Washington, 1884.

GILMORE, Q. A., On Limes, Hydraulic Cements, and Mortars, New York, 1888.

BUTLER, D. B., Portland Cement, its Manufacture, Testing and Uses, London and New York, 1899.

RIES, H., The Clays of the United States east of the Mississippi River, Professional Paper 11, U. S. Geol. Sur., Washington, 1903.

STEUART, W. M., Special Report of the Census Office on Mines and Quarries, Washington, 1905.

PALEONTOLOGIC GEOLOGY

ZITTEL, K. A., Grundzuge der paläontologie, München, 1903.

Handbuch der Paleontologie, München and Leipzig, 1876-92.

NICHOLSON, H. A., and LYDEKKER, R., Manual of Paleontology, London, 1889.

KOKEN, E., die Vorwelt und ihre Entwickelungsgeschichte, Leipzig, 1893.

WOODS, J. E. T., Elementary Paleontology for Geological Students, Cambridge, 1902.

ZITTEL, K. A., and EASTMAN, C. R., Textbook of Paleontology, London, 1900.

ROMER, F., and FRECH, F., Lethaea Geognostica, Stuttgart, 1880.

WALTHER, J., Einleitung in die Geologie, Jena, 1894.

BERNARD, F., Elements de Paléontologie, Paris, 1895.

ZEILLEB, R., Elements de Paléobotanique, Paris.

PERIODICAL PUBLICATIONS

Annales des Mines, published at Paris since 1794.

American Journal of Science, published in New Haven since 1819.

BOOKS FOR GENERAL REFERENCE FOR DEPARTMENT OF ANTHROPOLOGY

(*A brief list prepared by the courtesy of Professor Frederic W. Putnam, Harvard University and University of California.*)

ABBOTT, Primitive Industry.

AVEBURY (LUBBOCK), Prehistoric Times (last edition).

BROCA, Instructions Anthropologiques générales.

BRINTON, American Race; Maya Primer; Religions of Primitive People.

DAWKINS, Cave Hunting; Early Man in Britain and his place in the Tertiary Period.

DENIKER, Races of Men.

EVANS, Ancient Stone Implements of Great Britain; Ancient Bronze Implements of Great Britain.

FARRAND, Basis of American History (vol. II, The American Nation).

FRAZER, The Golden Bough; Totemism.

GROSSE, Beginnings of Art.

HADDON, Evolution in Art.

HALE, The Iroquois Book of Rites.

JESPERSEN, Progress in Language.

JOLY, Man before Metals.

KEAN, Ethnology.

KINGSLEY, West African Studies.

LANG, Myth, Ritual and Religion.

LETORNEAU, Property, its Origin and Development.

LUBBOCK (AVEBURY), Primitive Law.

MORTILLET, Les Préhistorique.

MUNRO, Lake Dwellings of Europe.

NADAILLAC, Prehistoric America.

POWELL, Introduction to the Study of American Languages.

RATZEL, History of Mankind.

RIPLEY, Races of Europe.

SCHULTZE, Fetichism.

SHORT, North Americans of Antiquity (2d edition).

SPENCER and GILLAN, Native Tribes of Central Australia; The Northern Tribes of Central Australia.

STARCKE, The Primitive Family; Its Origin and Development.

STEPHENS, Incidents of Travel in Yucatan; Incidents of Travel in Central America, Chiapas and Yucatan.

SWEET, History of Language.

TOPINARD, Eléments d'Anthropologie générale.
TYLOR, Primitive Culture (latest edition).
WESTERMARCK, History of Human Marriage.
WHITNEY, Language and Study of Language; Life and Growth of Language.

Anthropological Journals and Publications of Societies and Museums.

Academy of Natural Sciences (C. B. Moore's Memoirs on the Archæology of the Gulf States).
American Anthropologist.
American Antiquarian.
American Antiquarian Society, Proceedings of.
American Folk-Lore Society, Journal and Memoirs of.
Archæological Institute of America, Journal of.
Essex Institute, Bulletins of.
Ohio Archæological and Historical Quarterly.
Smithsonian Institution, Annual Reports and Contributions to Knowledge.
U. S. Bureau of American Ethnology, Annual Reports and Bulletins.
U. S. National Museum, Annual Reports.
U. S. Ethnological Survey of the Philippines.
American Museum of Natural History, New York, Memoirs, Bulletins and Journals.
University of California Publications: Anthropological Department.
Field Columbian Museum, Publications of Anthropological Department.
Free Museum of Science and Art, University of Pennsylvania, Bulletins and Transactions.
New York State Museum, Albany, Bulletins (Archæological Series).
Peabody Museum of Harvard University, Memoirs, Papers and Special Publications.
Anthropological Institute of Great Britain and Ireland, Journal of.
Anthropological Institute of Great Britain and Ireland, "Man."
Archiv für Anthropologie.
Globus.
L'Anthropologie.
London Folk-Lore Society, Journal of.
Internationales Archiv für Ethnographie.
Petermanns Mitteilungen.
Zeitschrift für Ethnologie.
Museums and Societies of Berlin, Bombay, Buenos Ayres, Brussels, Dresden, Florence, Leiden, Leipsic, Lyons, Madrid, Mexico, Moscow, Munich, Paris, Riga, St. Petersburg, Stockholm, Trondhjem, Upsala, Vienna, Wellington (N. Z.), etc., Publications of.

THE RECENT DEVELOPMENT OF BIOLOGY

BY JACQUES LOEB

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I

THE task allotted to me on this occasion is a review of the development of biology during the last century. The limited time at our disposal will necessitate many omissions and will force me to confine myself to the discussion of a few of the departures in biology which have led or promise to lead to fertile discoveries.

The problem of a scientific investigator can always be reduced to two tasks; the first, to determine the independent variables of the phenomena which he has under investigation, and secondly, to find the formula which allows him to calculate the value of the function for every value of the variable. In physics and chemistry the independent variables are in many cases so evident that the investigation may begin directly with the quantitative determination of the relation between the change of the essential variable and the function. In biology, however, the variables, as a rule, cannot be recognized so easily, and a great part of the

mental energy of the investigators must be spent in the search for these variables. To give an example, we know that in many eggs the development only begins after the entrance of a spermatozoön into the egg. The spermatozoön must produce some kind of a change in the egg, which is responsible for the development. But we do not know which variable in the egg is changed by the spermatozoön, whether the latter produces a chemical or an osmotic change, or whether it brings about a change of phase or some other effect. It goes without saying that a theory of sexual fertilization is impossible until the independent variable in the process of sexual fertilization is known.

The investigations of the biologist differ from those of the chemist and physicist in that the biologist deals with the analysis of the mechanism of a special class of machines. Living organisms are chemical machines, made of essentially colloidal material, which possess the peculiarity of developing, preserving, and reproducing themselves automatically. The machines which have thus far been produced artificially lack the peculiarity of developing, growing, preserving, and reproducing themselves, though no one can say with certainty that such machines might not one day be constructed artificially.

The specific and main work of the biologist will, therefore, he directed toward the analysis of the automatic mechanisms of development of self-preservation and reproduction.

II. *The Dynamics of the Chemical Processes in Living Organisms*

The progress made by chemistry, especially physical chemistry, has definitely put an end to the idea that the chemistry of living matter is different from the chemistry

of inanimate matter. The presence of catalyzers in all living tissues makes it intelligible that in spite of the comparatively low temperature at which life phenomena occur the reaction velocities for the essential processes in living organisms are comparatively high. It has been shown, moreover, that the action of the catalyzers found in living organisms can be imitated by certain metals or other inorganic catalyzers. We may, therefore, say that it is now proved beyond all doubt that the variable in the chemical processes in living organisms are identical with those with which the chemist has to deal in the laboratory. As a consequence of this result chemical biology has during the last years entered into the series of those sciences which are capable of predicting their results quantitatively. The application of the theory of chemical equilibrium to life phenomena has led biological chemists to look for reversible chemical processes in living organisms, and the result is the discovery of the reversible enzyme actions, which we owe to A. C. Hill. I think it marks the beginning of a new epoch of the physiology of metabolism that we now know that the same enzymes not only accelerate the hydrolysis, but also in some cases, if not generally, the synthesis of the products of cleavage. It is not impossible that the results thus obtained in the field of biology will ultimately in return benefit chemistry, inasmuch as they may enable chemistry to accomplish syntheses with the help of enzymes found in living organisms which could otherwise not be so easily obtained.

A very beautiful example of the conquest of biological chemistry through chemical dynamics is offered by the work of Arrhenius and Madsen. These authors have successfully applied the laws of chemical equilibrium to toxins and antitoxins so that it is possible to calculate the degree of saturation between toxins and antitoxins for any concentra-

tion with the same ease and certainty as for any other chemical reaction.

We know as yet but little concerning the method by which enzymes produce their accelerating effects. It seems that the facts recently gathered speak in favor of the idea of intermediary reactions. According to this idea the catalyzers participate in the reaction, but form combinations that are again rapidly decomposed. This makes it intelligible that at the end of the reaction the enzymes and catalyzers are generally in the same condition as at the beginning of the reaction, and that a comparatively small quantity of the catalyzer is sufficient for the transformation of large quantities of the reacting substances.

This chapter should not be concluded without mentioning the discovery of zymase by Buchner. It had long been argued that only certain of the fermentative actions of yeast depended on the presence of enzymes which could be separated from the living cells, but that the alcoholic fermentation of sugar by yeast was inseparably linked together with the life of the cell. Buchner showed that the enzyme which accelerates the alcoholic fermentation of sugar can also be separated from the living cell, with this purely technical difference only, that it requires a much higher pressure to extract zymase than any other enzymes from the yeast cell.

III. *Physical Structure of Living Matter*

We have stated that living organisms are chemical machines whose framework is formed by colloidal material consisting of proteins, fatty compounds, and carbohydrates. These colloids possess physical qualities which are believed to play a great rôle in life phenomena. Among these qualities are the slow rate of diffusion, the existence of a double layer of electricity at the surface of the dissolved or suspended col-

loidal particles, and the production of definite structures when they are precipitated. We may consider it as probable that the cytological and histological structures of living matter will be reduced to the physical qualities of the colloids. But, inasmuch as the physics of the colloids is still in its beginning, we must not be surprised that the biological application of its results is still in the stage of mere suggestions. The most important result which has thus far been accomplished through the application of the physics of colloids to biology is Traube's invention of the semi-permeable membranes. To Traube we owe the discovery that every living cell behaves as if it were surrounded with a surface film which does not possess equal permeability for water and the substances dissolved in it. Salts which are dissolved in water, as a rule, migrate much more slowly into the living cells than water. This discovery of the semi-permeability of the surface films of living protoplasm made it possible to recognize the variable which determines the exchange of liquids between protoplasm and the liquid medium by which it is surrounded, namely, the osmotic pressure. Inasmuch as the osmotic pressure is measurable, this field of biology has entered upon a stage where every hypothesis can be tested exactly, and biology is no longer compelled to carry a ballast of shallow phrases. We are now able to analyze quantitatively such functions as lymph formation and the secretion of glands.

Recent investigations have thrown some light on the nature of the conditions which seem to determine the semi-permeability of living matter. Quincke had already mentioned that a film of oil acts like a semi-permeable membrane. From certain considerations of surface tension and surface energy it follows that every particle of protoplasm which is surrounded by a watery liquid must form an extremely thin film of oil at its surface. Overton has recently shown that

of all dissolved substances those which possess a high solubility in fat, *e. g.*, alcohol, ether, chloroform, diffuse most easily into living cells. Overton concludes that lipoid substances, such as lecithin and cholesterin, which are found in every cell, determine the phenomenon of the semi-permeability of living matter.

IV. *Development and Heredity.*

We now come to the discussion of those phenomena which constitute the specific difference between living machines and the machines which we have thus far been able to make artificially. Living organisms show the phenomena of development. During the last century it was ascertained that the development of an animal egg, in general, does not occur until a spermatozoön has entered it, but as already stated, we do not know which variable in the egg is changed by the spermatozoön. An attempt has been made to fill the gap by causing unfertilized eggs to develop with the aid of physicochemical means. The decisive variable by which such an artificial parthenogenesis can be best produced is the osmotic pressure. It has been possible to cause the unfertilized eggs of echinoderms, annelids, and mollusks to develop into swimming larvæ by increasing transitorily the osmotic pressure of the surrounding solution. Even in vertebrates (the frog and petromyzon), Bataillon has succeeded in calling forth the first processes of development in this way. In other forms specific chemical influences cause the development, *e. g.*, in the eggs of starfish diluted acids, and, best of all, as Delage has shown, carbon dioxide. In the eggs of *Chætopterus* potassium salts produce this result, and in the case of *Amphitrite*, calcium salts.

From a sexual cell only a definite organism can arise, whose properties can be predicted if we know from which

organism the sexual cell originates. The foundations of the theory of heredity were laid by Gregory Mendel in his treatise on the *Hybrids of Plants*, one of the most prominent papers ever published in biology. Mendel showed in his experiments that certain simple characteristics, as, for example, the round or angular shape of the seeds of peas or the color of their endosperm, is already determined in the germ by indefinite determinants. He showed, moreover, that in the case of the hybridization of certain forms one half of the sexual cells of each child contains the determinants of the one parent, the other half contains the determinants of the other parent. In thus showing that the results of hybridization can be predicted numerically, not only for one, but for a series of generations, according to the laws of the calculus of probability, he gave not a hypothesis, but an exact theory of heredity. Mendel's experiments remained unnoticed until Hugo de Vries discovered the same facts anew, and at the same time became aware of Mendel's treatise.

The theory of heredity of Mendel and de Vries is in full harmony with the idea of evolution. The modern idea of evolution originated, as is well known, with Lamarck, and it is the great merit of Darwin to have revived this idea. It is, however, remarkable that none of the Darwinian authors seemed to consider it necessary that the transformation of species should be the object of direct observation. It is generally understood in the natural sciences either that direct observation should form the foundation of our conclusions or mathematical laws which are derived from direct observations. This rule was evidently considered superfluous by those writing on the hypothesis of evolution. Their scientific conscience was quieted by the assumption that processes like that of evolution could not be directly observed, as they occurred too slowly, and that for this

reason indirect observations must suffice. I believe that this lack of direct observation explains the polemical character of this literature, for wherever we can base our conclusions upon direct observations polemics become superfluous. It was, therefore, a decided progress when de Vries was able to show that the hereditary changes of forms, so-called "mutations," can be directly observed, at least in certain groups of organisms, and secondly, that these changes take place in harmony with the idea that for definite hereditary characteristics definite determinants, possibly in the form of chemical compounds, must be present in the sexual cells. It seems to me that the work of Mendel and de Vries and their successors marks the beginning of a real theory of heredity and evolution. If it is at all possible to produce new species artificially, I think that the discoveries of Mendel and de Vries must be the starting point.

It is at present entirely unknown how it happens that in living organisms, as a rule, larger quantities of sexual cells begin to form at a definite period in their existence. Miescher attempted to solve this problem in his researches on the salmon. But it seems that Miescher laid too much emphasis upon a mere secondary feature of this phenomenon, namely, that the sexual cells in the salmon apparently develop at the expense of the muscular substance of the animal. According to our present knowledge of the chemical dynamics of the animal body it seems rather immaterial whether the proteins and other constituents of the sexual cell come from the body of the animal or from the food taken up. The causes which determine the formation of large masses of sexual cells in an organism at a certain period of its existence are entirely unknown.

A little more progress has been made in regard to another problem which belongs to this group of phenomena,

namely, how it happens that in many species one individual forms sperm, the other eggs. It has been known for more than a century that it is possible to produce at desire either females exclusively, or both sexes, in plant lice. In bees and related forms, as a rule at least, only males originate from the unfertilized eggs; from the fertilized eggs only females. It is, moreover, known that in higher vertebrates those twins which originate from one egg have the same sex, while the sex of twins originating from different eggs may be different. All facts which as thus far known in regard to the determination of sex seem to indicate that the sex of the embryo is already determined in the unfertilized egg, or at least immediately after fertilization. I consider it possible that in regard to the determination of sex, just as in the case of artificial parthenogenesis, a general variable will be found by which we can determine whether an egg cell will assume male or female character.

V. *Instinct and Consciousness*

The difference between our artificial machines and the living organisms appears, perhaps, most striking when we compare the many automatic devices by which the preservation of individuals and species is guaranteed. Where separate sexes exist we find automatic arrangements by which the sexual cells of the two sexes are brought together. Wherever the development of the eggs and larvæ occurs outside of the body of the mother or the nest we often find automatic mechanisms whereby the eggs are deposited in such places as contain food on which the young larva can exist and grow. We have to raise the question how far has the analysis of these automatic mechanics been pushed. Metaphysics has supplied us with the terms "instinct" and "will" for these phenomena. We speak of in-

stinct wherever an animal performs, without foresight of the ends, those acts by which the preservation of the individual or the species is secured. The term "will" is reserved for those cases where these processes form constituents of consciousness. The words "instinct" and "will" do, however, not give us the variables by which we can analyze or control the mechanism of these actions. Scientific analysis has shown that the motions of animals which are directed towards a definite aim depend upon a mechanism which is essentially a function of the symmetrical structure and the symmetrical distribution of irritability. Symmetrical points of the surface of an animal, as a rule, have the same irritability, which means that, when stimulated equally, they produce the same quantity of motion. The points at the oral pole as a rule possess a qualitatively different or greater irritability than those at the aboral pole. If rays of light or current curves, or lines of diffusion or gravitation, start from one point and strike an organism, which is sensitive for the form of energy involved, on one side only, the tension of the symmetrical muscles or contractile elements does not remain the same on both sides of the body, and a tendency for rotation will result. This will continue until the symmetrical points of the animal are struck equally. As soon as this occurs there is no more reason why the animal should deviate to the right or left from the direction of its plane or axis of symmetry. These phenomena of automatic orientation of animals in a field of energy have been designated at tropisms. It has been possible to dissolve a series of mysterious instincts into cases of simple tropisms. The investigation of the various cases of tropism has shown their great variety, and there can be no doubt that further researches will increase the variety of tropisms and tropism-like phenomena. I am inclined to believe that we possess

in the tropisms and tropism-like mechanisms the independent variable of such functions as the instinctive selection of food and similar regulatory phenomena.

As far as the mechanism of consciousness is concerned, no scientific fact has thus far been found that promises an unraveling of this mechanism in the near future. It may be said, however, that at least the nature of the biological problem here involved can be stated. From a scientific point of view we may say that what we call consciousness is the function of a definite machine which we will call the machine of associative memory. Whatever the nature of this machine in living beings may be, it has an essential feature in common with the phonograph, namely, that it is capable of reproducing impressions in the same chronological order in which they come to us. Even simultaneous impressions of a different physical character, such as, for instance, optical and acoustical, easily fuse in memory and form an inseparable complex. The mechanism upon which associative memory depends seems to be located, in higher vertebrates at least, in the cerebral hemispheres, as the experiments of Goltz have shown. The same author has shown, moreover, that one of the two hemispheres suffices for the efficiency of this mechanism and for the full action of consciousness. As far, however, as the physical or chemical character of the mechanism of memory is concerned, we possess only a few starting points. We know that the nerve cells are especially rich in fatty constituents, and Hans Meyer and Overton have shown that substances which are easily soluble in fat also act as very powerful anæsthetics, for instance, chloroform, ether, and alcohol, and so on. It may be possible that the mechanism of associative memory depends in some way upon the constitution or action of the fatty compounds in our nerve cells. Another fact which may prove of importance is the obser-

vation made by Speck that if the partial pressure of oxygen in the air falls below one-third of its normal value, mental activity very soon becomes impaired and consciousness is lost. Undoubtedly the unraveling of the mechanism of associated memory is one of the greatest discoveries which biology has still in store.

VI. *Elementary Physiological Processes.*

It is, perhaps, possible that an advance in the analysis of the mechanism of memory will be made when we shall know more about the processes that occur in nerve cells in general. The most elementary mechanisms of self-preservation in higher animals are the respiratory motions and the action of the heart. The impulse for the respiratory action starts from the nerve cells. As far as the impulses for the activity of the heart are concerned, we can say that in one form at least they start from nerve cells, and in all cases from those regions where nerve cells are situated. But as far as the nature of these impulses is concerned we know as little about the cause of the rhythmical phenomena of respiration and heart-beat as we know concerning the mechanism of associative memory. It is rather surprising, but nevertheless a fact, that physiology has not progressed beyond the stage of mere suggestions and hypothesis in the analysis of such elementary phenomena as nerve action, muscular contractility, and cell division. Among the suggestions concerning the nature of contractility those seem most promising which take into consideration the phenomena of surface tension. The same lack of definite knowledge is found in regard to the changes in the sense organs which give rise to sensations. It is obvious that the most striking gaps in biology are found in that field of biology which has been cultivated by the

physiologists. The reason for this is, in part, that the analysis of the elementary protoplasmic processes is especially difficult, but I believe that there are other reasons. Medical physiologists have confined themselves to the study of a few organisms, and this has had the effect that for the last fifty years the same work has been repeated with slight modifications over and over again.

VII. *Technical Biology*

I think the creation of technical biology must be considered the most significant turn biology has taken during the last century. This turn is connected with a number of names, among which Liebig and Pasteur are the most prominent. Agriculture may be considered as an industry for the transformation of radiating into chemical energy. It was known for a long time that the green plants were able to build up, with the help of the light, the carbohydrates from the carbon dioxide of the air. Liebig showed that for the growth of the plant definite salts are necessary, that these salts are withdrawn from the soil by the plants, and that in order to produce crops these salts must be given back to the soil. One important point had not been cleared up by the work of Liebig, namely, the source of nitrates in the soil which the plants need for the manufacture of their proteins. This gap was filled by Hellriegel, who found that the tubercles of the leguminosæ, or rather the bacteria contained in these tubercles, are capable of transforming the inert nitrogen of the air into a form in which the plant can utilize it for the synthesis of its proteins. Winogradski subsequently discovered that not only the tubercle bacteria of leguminosæ are capable of fixing the nitrogen of the air in the soil in a form in which it can be utilized by the plant, but that the same can be done by cer-

tain other bacteria, for instance, *Chlostridium pasteurianum*. These facts have a bearing which goes beyond the interests of agriculture. The question of obtaining nitrates from the nitrogen of the air is of importance also for chemical industry, and it is not impossible that chemists may one day utilize the experience obtained in nitrifying bacteria.

With the discovery of the culture of nitrifying bacteria we have already entered the field of Pasteur's work. Yeast had been used for the purposes of fermentation before Pasteur, but Pasteur freed this field of biology just as much from the influence of chance as Liebig did in the case of agriculture. The chemist Pasteur taught biologists how to discriminate between the useful and harmful forms of yeast and bacteria, and thus rendered it possible to put the industry of fermentation upon a safe basis.

In recent times the fact has often been mentioned that the coal fields will be exhausted sooner or later. If this is true, every source of available energy which is neglected to-day may one day become of importance. Professor Hensen has recognized the importance of the surface of the ocean for the production of crops. The surface of the ocean is inhabited by endless masses of microscopic organisms which contain chlorophyl, and which are capable of transforming the radiating energy of the sun into chemical energy.

Not only through the industry of fermentation and agriculture has technical biology asserted its place side by side with physical and chemical technology, but also in the conquest of new regions for civilization. As long as tropical countries are continually threatened by epidemics, no steady industrial development is possible. Biology has begun to remove this danger. It is due to Koch if epidemics of cholera can be suppressed to-day, and to Yersin if the spreading of plague can now be prevented. Theobald

Smith discovered that the organisms of Texas fever are carried by a certain insect, and this discovery has had the effect of reducing, and possibly in the near future destroying, two dreaded diseases, namely, malaria and yellow fever.

It is natural that the rapid development of technical biology has reacted beneficially upon the development of theoretical biology. Just as physics and chemistry are receiving steadily new impulses from technology, the same is true for biology. The working out of the problems of immunity has created new fields for theoretical biology. Ehrlich has shown that in the case of immunity toxins are rendered harmless by their being bound by certain bodies, the so-called antitoxins. The investigation of the nature and the origin of toxins in the case of acquired immunity is a new problem which technical biology has given to theoretical biology. The same may be said in regard to the experiments of Pfeifer and Bordet on bacteriolysis and hemolysis. Bordet's work has led to the development of methods which have been utilized for the determination of the blood relationship of animals.

VIII. *Ethical and Economic Effects of Modern Biology*

The representatives of the mental sciences often reproach the natural sciences that the latter only develop the material, but not the mental or moral interests of humanity. It seems to me, however, that this statement is wrong. The struggle against superstition is entirely carried on by the natural sciences, and especially by the applied sciences. The nature of superstition consists in a gross misunderstanding of the causes of natural phenomena. I have not gained the impression that the mental sciences have been able to reduce the amount of superstition. Lourdes and Mecca are in no

danger from the side of the representatives of the mental sciences, but only from the side of scientific medicine. Superstition disappears so slowly for the reason that the masses as a rule are not taught any sciences. If the day comes when the chief laws of physics, chemistry, and experimental biology are generally and adequately taught, we may hope to see superstition and all its consequences disappear, but not before this.

As far as the influence of the applied sciences on ethics is concerned, I think we may hope that through the natural sciences the ethics of our political and economical life will be altered. In our political as well as our economical life we are still under the influence of the ancients, especially the Romans, who knew only one means of acquiring wealth, namely, by dispossessing others of it. The natural sciences have shown that there is another and more effective way of acquiring wealth, namely, by creating it. The way of doing this consists in the invention of means by which the store of energy present in nature can be more fully utilized. The wealth of modern nations, of Germany and France, is not due to their statesmen or to their wars, but to the accomplishments of the scientists. It had been calculated that the inventions of Pasteur alone added a billion francs a year to the wealth of France. In the light of such facts it seems preposterous that statesmen should continue to instigate war simply for the conquest of territories. Through modern science the wealth of a nation can be increased much more quickly than through any territorial conquest. We cannot expect any change in the political and economical ethics of nations until it is recognized that the lawmakers and statesmen must have a scientific training. If our lawmakers possessed such a training, they would certainly not have allowed one general source of energy after another, such as oil-fields, coal-fields, water-power, etc., to

be appropriated by individuals. All these stores of energy belong just as well to the community as the oxygen of the air or the radiating energy of the sun. Our present economical and political ethics is still on the whole that of the classical period or the Renaissance, because the knowledge of science among the masses and statesmen is still on that level, but the natural sciences will ultimately bring about as thorough a revolution in ethics as they have brought about in our material life.

IX. *Experimental Biology as an Independent Science*

If we compare the development of biology with the simultaneous development of physics and chemistry during the last twenty years, we must be impressed by the fact that during that time the great discoveries in physics and chemistry have followed each other surprisingly fast. The discovery of the law of osmotic pressure, the theory of electrical dissociation, the theory of galvanic batteries, the systematic formulation of physical chemistry, the discovery of electrical waves, the discovery of the X-rays, the discovery of the new elements in the air, the discovery of radioactivity, the transformation of radium into helium, the theory of radiation pressure,—what have we in biology that could be compared with such a series of discoveries? But I believe that biology has important discoveries in store, and that there is no intrinsic reason why it should be less fertile than physics and chemistry. I think the difference in the fertility of biology and the physical sciences is at least partly due to the present organization of the biological sciences.

General or experimental biology should be represented in our universities by special chairs and laboratories. It should be the task of this science to analyze and control

those phenomena which are specifically characteristic of living organisms, namely, development, self-preservation, and reproduction. The methods of general biology must be those of chemistry, and especially those of physical chemistry. To-day general or experimental biology is represented in our universities neither by chairs nor by laboratories. We have laboratories for physiology, but to show how little interest physiologists take in general biology I may mention the fact that the editor of a physiological annual review excludes papers on development and fertilization from his report, as, in his opinion, this belongs to anatomy. On the other hand, anatomists and zoölogists must give their full energy to their morphological investigations, and have, as a rule, neither the time for experimental work, nor very often the training necessary for that kind of work. Only the botanists have kept up their interest in general biology, but they of course pay no attention to animal biology. In working out this short review of the development of biology during the last century, I have been impressed with the necessity of our making better provisions for that side of biology where, in my opinion, the chances for the great discoveries seem to lie, namely, *general* or *experimental* biology.

THE PROBLEM OF THE ORIGIN OF SPECIES

BY CHARLES OTIS WHITMAN

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The problem of problems in biology to-day—the problem which promises to sweep through the present century as it has the past one, with cumulative interest and correspondingly important results—is the one which became the life-work of Charles Darwin, and which cannot be better or more simply expressed than in the title of his epoch-making book,—*The Origin of Species.*

Darwin certainly made this problem one of universal interest, and no one will deny that the work which he did has revolutionized both the morphological and the physiological branches of biology. Indeed, no field of thought has escaped the leavening influence of his conclusions.

The prevailing belief up to Darwin's time that species were immutable forms, each separately designed and fashioned by the Creator, and each endowed with all its instincts and equipped with a structural organization perfectly adapted to its prescribed sphere of life,—this old belief was certainly effectually exploded, and is now passing into oblivion.

With one mighty stroke Darwin released biology from the thralldom of supernaturalism. In the place of special creations and cataclysmal revolutions, he set up progressive evolution through the operation of simple natural laws. To unveil that sacred mystery of mysteries, and reduce it to the level of natural laws, was a shock to all Christendom. The idea of a self-regulating, progressive evolution of species appeared, even to many eminent men of science, to be a "heresy." This was the case with Sir John Herschel, and even Sir Charles Lyell was at first of the same opinion, although he soon became convinced that natural laws were just as efficient and uniform in operation in the organic as in the inorganic world.

The outcome is familiar history. The sciences all the way up to psychology have experienced a wonderful renascence, and the world at large has moved forward in sympathetic accord to the close of a truly "Wonderful Century."

Few, however, would now claim that Darwin's solution was entirely conclusive and complete. From the nature of the case, Darwin could not exhaust the problem, and no one has made this clearer than Darwin himself, who examined his own theory with such critical acumen and breadth of knowledge that he anticipated nearly every important objection that has since been urged by others. A problem that is at once the focal point of each and every one of the biological sciences is not to be exhausted by one man, however long and successful his work. The problem has grown larger rather than smaller with every new contribution to its solution. The expansion of its horizon, however, has not, and as I believe, is not likely to disclose the "death-bed of Darwinism." We have heard the predictions, but have witnessed no fulfillment.

Among the rival theories of natural selection two are especially noteworthy. One of these is now generally

known as *orthogenesis.*[1] Theodore Eimer was one of the early champions of this theory, basing his arguments primarily upon his researches on the variation of the wall-lizard (1874-81). Eimer boldly announced his later works on *The Origin of Species* (1888), and the *Orthogenesis of the Butterflies* (1897), as furnishing *complete proof of definitely directed variation, as the result of the inheritance of acquired characters, and as showing the utter "impotence of natural selection."* Eimer's intemperate ferocity toward the views of Darwin and Weismann, coupled with an almost fanatical advocacy of the notion that organic evolution depends upon the inheritance of acquired characters, was enough to prejudice the whole case of orthogenesis. Moreover, the controversial setting given to the idea of definitely directed variation, without the aid of utility and natural selection, made it difficult to escape the conclusion that orthogenesis was only a new form of the old teleology, from the paralyzing domination of which Darwin and Lyell and their followers had rescued science. Thus handicapped, the theory of orthogenesis has found little favor outside the circle of Eimer's pupils.

The second of the two theories alluded to is the mutation theory of Hugo de Vries. The distinguished author of this theory, whose presence honors this International Congress, and lends special *éclat* to the Section of Phylogeny, maintains, on the basis of long-continued experimental research, that species originate, not by slow, gradual variation, as held by Darwin and Wallace, but by sudden *saltations,* or sport-like mutations. According to this theory, two fundamentally distinct phenomena have hitherto been confounded under the term variation. In other words, variation, as used by Darwin and others, covers two classes of phenomena, totally distinct in nature, action, and effect. Variation proper is defined as the ordinary, fluctuating, or in-

[1] A name introduced by Wilhelm Haacke (*Gestaltung und Vererbung,* p. 31).

dividual variation, and this is held to be absolutely impotent to form new species.

It is claimed that no amount of either natural or artificial selection can by any possibility lead this variation up to the birth of a new species. The utmost that could be attained would be an improved race that would inevitably revert to the original state as soon as left to itself.

Mutation, on the other hand, never advances by slow and minute modifications, which are continuous and cumulative, but by single, sudden jumps. In the words of De Vries: "Species have not arisen through gradual selection, continued for hundreds or thousands of years, but by jumps (*stufenweise*) through sudden, though small, transformations. In contrast with variations which are changes advancing in a *linear direction,* the transformations to be called mutations diverge in *new directions.* They take place, then, so far as experience goes, without definite direction." (Vol. I, p. 150.)

The new species arises from the old, but without any visible preparatory steps, and without intermediate connecting stages. Like the old, it is subject to variation, but as a type, it is essentially immutable.

De Vries does not deny that variation produces what may appear to be transitional forms, but he maintains that these forms in reality have no such meaning. They are to be regarded as phenomena of "transgressive variability," which may obscure, but not obliterate the specific limits.

"For," says De Vries, "the transitions do not appear before the new species, at most only simultaneously with this, and generally only after this is already in existence. The transitions are therefore no intermediates or preparations for the appearance of the new forms. The origin takes place, not through them, but wholly independently of them." (Vol. I, p. 362.)

Granting that the position with respect to the mutants obtained from the evening primrose (*Enothera Lamarckiana*) is unassailable, does it follow that *all* new species have arisen by mutation, and that continuous variation has never had, and never can have, anything to do with the origin of species?

Plausible as is the argument and impressive as is the array of evidence presented, I can but feel that there are reasons which compel us to suspend judgment for a while on this pivotal point of the mutation theory. America is the original home of the evening primroses, and it is here that the natural history of the group remains to be worked out in the light of the experimental results obtained in Holland.

What does it mean that a few mutants keep on reappearing year after year, and that even the mutants themselves mutate, not in new lines, but in the same old ones? Persuaded as deeply as I am that we can never draw from a species anything for which no ancestral foundations preëxist, I anticipate that our wild evening primroses have revelations to make.

Whatever revelations may await future investigation in this field, the work done in the Primrose Garden of Amsterdam will stand as a classical contribution to the new biology, and as one of the very best models in method of research that we have yet seen.

Natural selection, orthogenesis, and mutation appear to present fundamental contradictions; but I believe that each stands for truth, and that reconciliation is not distant.

The so-called mutations of *Ænothera* are indubitable facts; but two leading questions remain to be answered. First, are these mutations, now appearing, as is claimed, independently of variation, nevertheless the products of variations that took place at an earlier period in the history of

these plants? Secondly, if species can spring into existence at a single leap, without the assistance of cumulative variations, may they not also originate with such assistance? That variation does issue in new species, and that natural selection is a factor, though not the only factor, in determining results, is, in my opinion, as certain as that grass grows, although we cannot see it grow.

Furthermore, I believe I have found indubitable evidence of species-forming variation advancing in a definite direction (orthogenesis), and likewise of variations in various directions (amphigenesis). If I am not mistaken in this, the reconciliation for natural selection and orthogenesis is at hand.

I am aware that orthogenesis is held by many to be utterly incompatible with both natural selection and mutation. "The Darwinian principle demands," says De Vries, "that species-forming variability and mutability *be indeterminate in direction.* Deviation in all senses must arise, without favor to any particular direction, and especially without partiality for the direction proceeding from the theory to be explained. Every hypothesis which departs from this principle must be rejected as teleological, and therefore unscientific." (Vol. I, p. 140.)

Again (p. 180) the same point is amplified: "Again and again, and by authors of different aims, it has been insisted upon that species-forming variability must be *orderless.* The assumption of a *definite variation-tendency* which would condition, or even favor, the appearance of adaptive modifications, lies outside the pale of the natural science of to-day. In fact, the great advantage of Darwin's doctrine of selection lies in this, that it strives to explain the whole evolution of the animal and plant kingdoms without the aid of supernatural presuppositions. According to this doctrine, species-forming variability goes

on without regard to the qualification of the new species for maintaining themselves in life. It simply supplies the struggle for existence with the material for natural selection. Whether this selection takes place between individuals, as Darwin and Wallace supposed, or decides between whole species, as the mutation-theory demands, ultimately it is, in either case, simply the ability for existence under given external conditions that decides upon the permanence of the new form" (p. 180).

I take exception here only to the implication that a definite variation-tendency must be considered to be teleological because it is not "orderless." I venture to assert that variation is *sometimes* orderly, and at other times rather disorderly, and that the one is just as free from teleology as the other. In our aversion to the old teleology, so effectually banished from science by Darwin, we should not forget that the world is full of order, the organic no less than the inorganic. Indeed, what is the whole development of an organism if not strictly and marvelously orderly? Is not every stage, from the primordial germ onward, and the whole sequence of stages, rigidly orthogenetic? If variations are deviations in the directions of the developmental processes, what wonder is there if in some directions there is less resistance to variation than in others? What wonder if the organism is so balanced as to permit of both unifarious and multifarious variations? If a developmental process may run on throughout life (*e. g.*, the lifelong multiplication of the surface-pores of the lateral-line system in Amia), what wonder if we find a whole species gravitating slowly in one or a few directions? And if we find large groups of species all affected by a like variation, moving in the same general direction, are we compelled to regard such "a definite variation-tendency" as teleological, and hence out of the pale of science? If a *designer* sets limits to variation

in order to reach a definite end, the direction of events is teleological; but if organization and the laws of development exclude some lines of variation and favor others, there is certainly nothing supernatural in this, and nothing which is incompatible with natural selection. Natural selection may enter at any stage of orthogenetic variation, preserve and modify in various directions the results over which it may have had no previous control.

It has always appeared to be one of the greatest difficulties for natural selection to account for the incipient stages of useful organs. Orthogenesis, as I hope to make clear, removes this difficulty from a large portion of the field.

It should be noted in this connection that the difficulty of incipient stages is not what it is so generally presumed to be. The advocates of natural selection habitually assume that the evolution of an organ or character begins with an "infinitesimal rudiment," which has no way of emerging from its functionless state except through minute chance variations in various directions. In this assumption the problem is misconceived. The characters we meet with today have rarely, if ever, arisen by direct evolution from useless rudiments. When we know enough about a character to undertake to trace its genesis, the "rudiment" imagined to lie so near recedes, and we are led on, not to a "beginning," but to an antecedent; and if we are fortunate enough to be able to advance father, we come to another antecedent, and so on. The series of antecedents stretches ever as far as we can see. As we repeat this experience with different characters, looking always for the primordial rudiment, our childish faith in such "beginnings" gives way to the conviction that the chase is led by a phantom.

No one of our sense-organs, for example, can be traced to a rudiment, except in the embryological sense. The eye of the vertebrate may appear as a rudiment in the embryo,

but no one can doubt that it has had a phylogenetic history, the first term of which—if first there be—must have been very different from its present embryonic rudiment. To assume that the eye began in some indifferent variation that fluctuated or mutated, chance-wise, into a state of incipient utility, and was then developed in a direct line to its present stage of complex adaptations, either gradually or *per saltus,* would be hardly more satisfactory than appealing to a miraculous succession of miracles. It is impossible to believe that such a system of harmonious coadaptations could ever arise by mutation;[1] and selection, although playing a very important part in such achievements, is probably never equal to the whole task. Without the assistance of some factor having more continuous directive efficiency, selection would fail to bring out of the chaos of chance variation, or kaleidoscopic mutation, such progressive evolution as the organic world reveals.

In order to show that such a factor is essential, and that it is actually present, supplying the indispensable initial stages, and holding the master hand in the *general* direction of evolution, demonstrative evidence is, of course, required. Such evidence lies in *the history of specific characters.* But how shall we approach such a task, if no near-by rudiment is to be found as a starting-point? Rudiments and premutations are alike illusory in this regard, for their beginning is always and necessarily assumed to lie in the realm of the invisible and unknowable. If we are to keep always on ground that is open to investigation, we must find our starting-points in known stages. As the laws of nature are constant, it is not essential to trace entire histories. If some chapters are sufficiently open to observa-

[1] Darwin frequently emphasized the same objection. In a letter to Asa Gray, referring to the orchids, he remarks: "It is impossible to imagine so many coadaptations being formed, all by a chance blow."

Weismann has shown in a masterly manner how inadequate is the mutation theory to account for such phenomena.

tion and experiment to permit of close study, we may hope, in some of the more favorable cases, to read the phenomena in their natural order, and to learn from what goes on in one part of the history the factors that govern in all parts.

The study of the problem of the origin of species resolves itself, therefore, ever more clearly into exhaustive studies of single favorable characters, in the more accessible portions of their history.

For decisive evidence we must have characters of a comparatively simple nature, the evolutional records of which, in every case, are to be read in a considerable number of different species of known common origin.

It is a great mistake to resort exclusively to domestic races, for here the ancestry contains so many unknown elements that it is often impossible to refer phenomena to their proper sources. Even the so-called "pure breeds" are decidedly impure as compared with pure wild species. The ideal situation, as regards material, is to have pure wild species in abundance as the chief reliance, and allied domestic races for subsidiary purposes.

The pigeon amply fulfills all these prerequisites. A simple and convenient character, presenting divergent courses of evolution in some species and parallel courses in others, is to be found in the wing-bars and their homologues.

It is to some chapters in the history of this character that we may now turn for evidence that natural selection waits for opportunities, to be supplied, not by multifarious variation or orderless mutation, but by continuous evolutional processes advancing in definite directions.

The rock pigeons (*Columba livia*) present two very distinct color-patterns; one of which consists of black checkers uniformly distributed to the feathers of the wing and the back, the other of two black wing-bars on a slate-gray ground. These two patterns may be seen in almost any flock of domestic pigeons.

The inquiry as to the origin of these patterns involves the main problem of the origin of species, for the general principles that account for one character must hold for others, and so for the species as a whole. Darwin raised the same question, but did not pursue it beyond the point of trying to determine which pattern was to be considered original and how the derivation of the other was to be understood. Darwin's explanation was so simple and captivating that naturalists generally accepted it as final. It is but fair to state that Darwin's conclusions did not rest on a comparative study of the color-patterns displayed in the many wild species of pigeons. Accepting the view generally held by naturalists, that the rock pigeons must be regarded as the ancestors of domestic races, the question was limited to the point just stated.

It was known that the two types interbreed freely, under domestication, and it had been reported that checkered pigeons sometimes appeared as the offspring of two-barred pigeons. Moreover, Darwin discovered that the checkers were homologous with the spots composing the bars. As the main purpose was to show that variation was present to any extent required for the origin of new species, rather than to trace its course in any specific case, and as variation was supposed to be multifarious, and progress to be guided by natural selection of the "fittest," it is not strange that Darwin failed to get the direction of variation, or to realize that in *direction* is given the key to one of the fundamental laws of evolution.

As the two color-patterns are alike in having a common element, and differ chiefly in the number of elements, it was natural enough to take the smaller number as the point of departure, and to view the larger number as "an extension of these marks to other parts of the plumage." (*Animals and Plants,* vol. I, p. 225.) With the ancestral type thus

determined, and a simple mode of variation pointed out, Darwin could dismiss the problem with these words: "No importance can be attached to this natural variation in the plumage."

Whence and how the two bars arose was not explained. The mode of departure assumed to account for the checkered variety would, however, suggest that the bars themselves originated in the same manner; that is, from one or two spots arising *de novo,* as chance-variations, and the gradual extension of like spots in two rows of feathers. The one or more original spots, according to the general theory, would first appear as minute rudiments, and then be gradually enlarged and intensified by the aid of natural selection, guided by their utility as recognition marks.

Such a mode of origin would presuppose a plain, uniform gray ancestor, without any spots or bars in the wings, and would raise many puzzling questions that would be beyond the reach of investigation. For example: Why two bars? Why at the posterior end of the wing? Why do the spots taper backwards to a more or less sharp point in the checkered variety, while presenting a nearly square form in typical bars? Why should they have first extended upward, or downward, and in *two* rather than any other number of rows of feathers? If two rows of feathers were favored long enough to establish the bars for ornamental or other purposes, what freak of natural selection could have then interposed to turn a long-favored, definitely directed extension into a diffuse general extension, and thus to neutralize completely the very effects it was invoked to explain?

Natural selection could not be supposed to originate or to guide the first indifferent stages of new characters. Mutation would be equally helpless, and each step would leave a gulf of discontinuity,—a miracle that nature seems to abhor.

Turning from theoretical *impasses* to the facts, let us compare the two patterns.

In the checkered pattern all the feathers are marked alike—*no regional differentiation.* In the other type we have a conspicuous local differentiation, suggesting at once a higher stage of evolution. Checkered wings are to be found which vary all the way between a uniform marking and the barred type. If we arrange a number of unequally checkered wings in a series, running from the most to the least checkered, we shall see that the pattern approaches more and more nearly to that of two bars, as the checkers diminish in size and number. We shall notice that the pigment is reduced more rapidly in the anterior than in the posterior part of the wing.

As checkers are reduced, they gradually lose their sharp ends, and approximate the square or rounded form seen in the elements of the typical bars. The series shows a flowing gradation, that may be read forward or backward with equal facility. Darwin's view takes the bars as the starting-point and reads forward. Taking the checkered condition as the point of departure, the variation runs just as smoothly in the opposite direction. We here meet an ambiguity that is everywhere present in color-pattern problems—an ambiguity that is frequently overlooked with disastrous consequences. The only way to eliminate the difficulty is to take our evidence from several different sources, and when agreement is found for one direction, and disagreement for the other, the way is clear.

As an experiment, we may take one or more pairs of pure-bred, typically barred pigeons, and keep them isolated from checkered birds for several years, in order to see if the young ever advance toward the checkered type.

Another experiment should be tried for the purpose of seeing what can be done by working in just the opposite

direction. In this case we take checkered birds, selecting in each generation birds with the fewer and smaller checkers, and rejecting the others, in order to see if the process of reduction can be carried to the condition of three, two, and one bar, and finally, to complete obliteration of both checkers and bars, leaving the wing a *tabula rasa* of uniform gray color.

If these experiments are continued sufficiently far, it will be found from the second experiment that a gradual reduction of pigment to the extreme conditions named can be comparatively easily effected, and that the direction of reduction will always be the same, from before backward; while, from the first experiment, it will be seen that it is hopeless to try to advance in the opposite direction, from the bars forward to the checkered condition. No variations will appear in that direction, but such as do appear will take the opposite direction, tending to diminish the width of the bars and to weaken their color. It is in this way that we must account for the existence of some fancy breeds in which the bars have been wholly obliterated. The direction of evolution can never be reversed.

I have tried both experiments for eight years, and as both tell the same story as to the direction of variation, I am satisfied that further experiments will not essentially modify the results.

With reduction traveling from before backward, in the manner described, we get the bars in their typical number, form, and position, as *one of the necessary stages* of the process, and without appealing to *de novo* origin, incipient rudiments, etc.

But if bars originated in such simple fashion,—*the direction of evolution being precisely the same as that of embryological development*,—if the theory of rudiments must be abandoned in this case, do we not meet the same

theory again in any attempt to account for the checkers?

What kind of rudiments could be imagined? We might assume that minute flecks of pigment first appeared, one in each feather; and then, further, imagine that these purely chance originations happened to have some slight utility, and that natural selection did the rest. But it is just as difficult to account for a small as a large origin *de novo,* and the smaller it is, the more unfortunate it is for the theory of natural selection.

If we seek refuge in the doctrine of mutation, are we better off? Mutation hides itself in the undiscoverable pre-mutation, and so we have all the difficulty of an incipient stage, and no means of advancing by ordinary variation.

Fortunately we are not driven to either alternative, for the checkers arise neither as mutations nor as rudiments, but by direct and gradual modification of an earlier ancestral mark, which came with the birth of the pigeon phylum, as a heritage from still more distant avian ancestors.

This ancestral mark is a *dark spot* filling the whole central part of the feather, leaving only a narrow distal edge of a lighter color. This mark is still well preserved in some of the old-world turtle-doves—best in the Oriental turtle-dove of China and Japan. The checker of *C. livia* differs from the dark centre of *T. orientalis* only in form and in having a lateral position. Typically this spot appears in pairs, one on each side of the feather. The two spots represent the two halves of the old central spot, which becomes more or less deeply divided by the disappearance of pigment along the shaft of the feather. This change begins at the tip of the feather and advances inward, but usually more rapidly along the shaft than at the sides, thus resulting in two checkers with more or less pointed tips.

The direction of change again coincides with that of embryonic development, the tip of the feather, where it begins, being first in order of development.

In many checkered rock pigeons we may find in the dorsal (inner) feathers of the bars *undivided* central spots, which pass gradually into the typical checkers as we pass towards the lower (outer) ends of the bars. Transitional stages of various degrees thus connect the derived with the ancestral type in *one and the same individual,* and so demonstrate that the two specific marks are not separated by impassable mutation gaps.

While it is not necessary to go beyond the wild rock pigeons and the multitude of domestic races descended from them to learn that nature has here pursued *one chief direction of color variation,* always leaving an open door, however, to minor modifications and improvements through natural and artificial selection, it is, nevertheless, highly instructive to make a comparative study of the whole group of wild pigeons, in both adult and juvenal stages. It is in this field that we find the same lessons amplified and repeated in multitudinous ways, confirmation confirmed, convergence of testimony complete.

It will be sufficient here to cite a few examples.

In the little ground doves (*Champæplia passerina*) of Florida, Arizona, California, Central and South America, and the West Indies, we find the turtle-dove pattern preserved in the whole breast region and in the anterior, smaller coverts of the wings, while in the posterior portion of the wings we meet with lateral spots or checkers, of higher finish than in the rock pigeons. In many coverts of the wing, we find the dark centres more or less reduced, with the distal ends of their remnants in various stages of conversion into lateral spots. Here again we find most striking proof of gradual change from one specific type to another.

In the brilliant bronze-winged pigeon (*Phaps chalcoptera*) of Australia, we have still another combination type,

in which iridescent checkers coexist with the original dark centres. Here the checker seems to arise by direct differentiation of a lateral portion of the dark centre, the latter still occupying the original field and forming the ground within which the checker appears as a more highly colored spot. While the dark centre does not suffer any reduction in its field, it does lose considerably in intensity of color. The metallic spots are therefore probably built up by concentration of pigment at the expense of the dark centres. As these birds make great display of their colors in the breeding season, this departure from the orthogenetic trend of development may be attributed to natural selection.

The wild passenger pigeon (*Ectopistes*) bears checkers closely resembling those of the checkered rock pigeon, in form, color, and distribution. In this species the sexes are distinctly differentiated in color; and we have for comparison three stages in an ascending series; namely, the juvenal, the adult female, and the adult male. As in so many other birds, the male makes the widest departure from original conditions; the female occupies a lower plane; the young are nearly alike in both sexes, and may be said to recapitulate ancestral conditions with less modification than is seen in the adult of either sex.

In birds taken at random, I count in the left wing and scapulars 90 checkers in a juvenal, 51 in an adult female, and 25 in an adult male. This is pretty conclusive evidence that checkers are, or have been, disappearing in the species. Not only the number, but also the size of the checkers has been reduced. In the female the checkers are for the most part two or more times as large as in the male. The reduction in both respects has been greater in the interior than in the posterior half of the wing, and greater along the lower edge than in the middle and back regions.

In this species we may recognize at first sight the homo-

logues of the rock pigeon bars. On the secondaries of the female we find the homologue of the posterior bar, and on the first row of long coverts the homologue of the anterior bar. The latter is scarcely recognizable as a bar; for we see only five or six checkers in the upper half of the row, the lower half being without checkers. Nevertheless, this row represents, so far as it goes, the elements of a bar, which is already too far gone to have even a chance to attain the finish of a perfect bar.[1]

On the secondaries the checkers fall into juxtaposition, forming a continuous bar, with an irregular posterior outline, which indicates that the checkers have been unevenly reduced from behind. It is a rudely finished bar, which has sunk below the horizon of utility, if it was ever above it, and is now facing ultimate effacement. The reduction has advanced further in the male, with no improvement towards regularity of outline. Here it becomes quite certain that effacement advances from all sides, leaving but a small remnant of a bar confined to two or three feathers.

Glancing at the wing as a whole, in both young and old, it is plain that the process of obliteration is in progress over the entire checkered area. The elongated, sharp-pointed marks of the earlier pattern have rounded tips in the adult; the posterior bar is roughly emarginated; the number of checkers is reduced by a half or more; and some of the remaining ones are but little more than mere dots. It is also equally manifest that the process of reduction is making more rapid progress in the fore part of the wing and along its lower edge than elsewhere. There can be no mistake here as to the direction in which the phenomena are to be read. The direction is as certain as that the adult male stands in advance of the adult female, and still

[1] In the young, the checkers of this row are more numerous and much more sharply pointed at the ends. In both respects the juvenal pattern approaches more nearly a condition of general uniformity.

more in advance of the young bird. The significance of the case lies mainly in the fact that it is not an isolated or exceptional one. Many other species tell more or less perfectly the same story.

A parallel case, only carried still farther in the same direction, is found in the mourning dove (*Zenaidura*). The adult male and female differ but slightly, each having only about a dozen checkers visible on each side. These are confined to the scapulars, and to a few feathers at the posterior upper edge of the wing. In the young, they are more numerous, but less so than in the young passenger pigeon. The middle and fore parts of the wing in the adult have no visible checkers, but a few concealed ones which may be seen on lifting the overlying feathers. These concealed checkers, and other differences between old and young, show that the species had its origin in a checkered stock, and that its history has been analogous to that of the passenger pigeon.

The white-winged pigeon (*Melopelia leucoptera*) is a most instructive form. Although a much more highly accomplished bird in the arts of display of form, feathers, and voice, than the mourning dove, it has suffered a complete effacement of the checkers it once possessed in common with other members of the family. Indubitable proof of this is to be seen in the juvenal feathers, which, in some cases, exhibit a few pale vestigial spots in the last two rows of long coverts, at points where the checkers are usually best developed in checkered species. Another striking proof is to be found in the coverts and scapulars of the adult bird, where we find, on lifting the feathers, distinctly outlined areas, corresponding in shape and position with reduced checkers, but from which the black pigment has disappeared. These vestigial outlines, structurally defined,

were first noticed in a female bird of a dark shade.[1] The outlines were more perfect than in lighter birds obtained from Arizona and California.

Similar vestiges are present in the mourning dove, and here their identification as marks formerly filled out with black pigment is freed from every shadow of doubt by checkers in all stages of obliteration.

The large wood pigeon (*C. palumbus*) of Europe has departed still more widely from the turtle-dove type, having lost all its black spots except a few in the neck patches, which have retreated so far from the tips of the feathers as to be concealed. The gray plumage and the white streak along the edge of the wing mark a plane in the evolution of this bird very nearly identical with that of the white-winged pigeon. A little higher plane has been reached by our band-tailed pigeon of the Pacific coast, which is also a species of turtle-dove derivation, as shown in the neck-marking and in the voice and behavior.[2]

These illustrations, which could be extended into the hundreds, may be concluded with two cases, representing wide extremes, yet governed by the same law of progressive orthogenetic variation.

The crested pigeon of Australia (*Ocyphaps lophotes*) stands at one extreme, at the uppermost limit in the number of bands and in the perfection of finish. There are eleven, or at most twelve, parallel bands crossing the wing and scapulars transversely, each band marking a single row of feathers, with the regularity of zebra stripes. The width of these bands increases from before backward, beginning with a width of about ½ mm. and reaching 4 to 5 mm. on the tenth band. The eleventh band, located on

[1] Captured in Jamaica by Dr. Humphreys.

[2] Minute blotches of black were found in the longer scapulars of a few individuals. These are probably atavistic reminiscences of lost spots.

the long coverts, is especially interesting, as it begins above with narrow elements, like the preceding, but is continued, from the third or fourth feather onward, by elongated *checker-like spots.*

This band, or bar, is the homologue of the anterior bar in the rock pigeon, and furnishes a standing picture of transitional continuity from one character to another, and at the same time settles beyond dispute the direction variation has pursued. So clear and decisive is the case, that one might safely predict that this entire bar is destined to be reduced to the narrow band-type seen in the fore part of the wing. We have only to turn to a closely allied species, the white-breasted crested pigeon (*Lophophaps leucogaster*)[1] to find that it has already realized the prediction to the full, having every checker in this row converted into a typical band-element.

Moreover, the transformation has already begun in the first feather of the next and last row, so that the same prediction could be extended to this bar, which is the homologue of the posterior bar in the rock pigeon.

Glancing again at Ocyphaps, and looking at the wing as a whole, the course of transformation, its mode, direction, and future termination are all very clearly defined. The wing-pattern, as shown especially in the light edges of the juvenal plumage, takes us clear back to the turtle-dove type. Next came the checkered pattern similar to that of the primitive rock pigeon. Reduction of pigment, proceeding from before backward, fashioned the bilateral checkers from the uni-central spots. The reduction kept on in the same direction, shortening the checkers and transforming the rows successively into narrow bands, eventually reaching the eleventh row, where we find only one

[1] This bird is comparatively rare, and I have seen but a single pair that recently came to hand through the kindness of Frank M. Chapman.

or two complete steps, followed by a graded series of 4 to 6 steps, less and less decided, until we lose every trace of them. So finely graded are these steps in some females that it is difficult to locate the vanishing-point.

Unless the process of transformation is arrested by the extinction of the species, or through the intervention of some more potent modifying influences than have thus far appeared, the fate of both posterior bars is irrevocably sealed. Granting that natural selection may be credited with strengthening the iridescent splendor of these bars, I believe that the orthogenetic influences are bound to prevail here as in the white-breasted species.

But is there any direct proof that the transformation is actually making progress to-day? May not these transitional steps go on appearing generation after generation, without ever making any permanent progress?

We have to concede that we cannot follow the processes that reveal themselves in steps. We can at most only see what is done—not the doing. We are entirely in the dark as to the time required to carry the change through a single row of feathers. But we know that this has been done in three other species of the same family. We see that after it is done, *not before,* the transitional steps appear in the next and last row. Moreover,—and this is as close as we can hope to get to actual seeing,—we find that *progress of just the kind we are looking for is certainly made in passing from the juvenal to the adult plumage.* This is an ontogenetic change of a few weeks, which we can easily demonstrate by experiment to be progressive and continuous. The corresponding phylogenetic advance has left no other record, and hence we only know that it took time—that it was not a momentary salt. In the adult plumage, *one or two full steps are taken beyond the juvenal stage, and taken precisely at the points premarked by transitional*

steps. The number of transitional steps is increased at the same time.[1]

As the next and last illustration, I take a case in which the bars are verging to complete obliteration. The well-known wild stock dove (*C. œnas*) of Europe may serve as a convenient and instructive example. In this pigeon we find that reduction of the checkers has swept over the whole wing, leaving nothing except a few obsolete spots, which we recognize as vanishing elements of bars formerly more highly developed, and homologous with those of the rock pigeon.

Here we find what at first glance looks like extraordinary variability, suggesting mutations, incipient stages, bars *in statu nascendi*, etc. The selectionist and the mutationist could each find what he looks for. The first thing to decide is the *direction* in which the phenomena are to be read. Is it a positive, progressive upbuilding of new characters, or a negative, retrogressive weakening of old characters? I have already anticipated the answer, and will now briefly show how the direction of variation is decisively settled.

(1) These spots have every outward appearance of being reduced remnants, such as we get in passing from the checkered to the barred condition in rock pigeons. They are rounded or squarish in form, frequently irregular and thin at the edges, dull in color as if fading, etc.

(2) The smallest stages are not found on the exposed surface of the feathers, but lie *concealed* beneath the over-

[1] One point here should not escape attention; namely, that the transitional steps in Ocyphaps form a *linear* series; but there is nothing artificial or arbitrary about it. It is a small-number series, each element of which stands in an appointed place, and marks the height to which the transformation process rose at that point in its course. Such a series cannot be open to the objections which De Vries has very justly made against large-number series, the elements of which are collected at random and then arranged arbitrarily to display transitional continuity.

In the Ocyphaps series there is some fluctuation, the series varying in length, but always advancing in one predetermined direction like a tidal flow guided along a prepared channel, and flowing to varying distances, according to the initial momentum.

lapping feathers next above or in front. Concealed spots admit of but one interpretation. This pigeon is a not distant relative of the rock pigeon, has a similar gray ground, and is therefore probably moving in a parallel direction, only more advanced.

(3) The spots are found at the posterior end of the wing, near the upper edge, on one to three tertials and on a few long coverts. In some cases they occur also on a few of the second row of long coverts, but here they are always very small and completely concealed. They are thus in the position occupied by vanishing spots generally.

(4) The adult plumage makes no advance in the number of spots, and some spots (second row of long coverts) visible in the young, are completely concealed in the adult. This indicates degeneration unmistakably.

(5) The stock dove, although sometimes having a concealed third bar of few spots, never appears in checkered dress. It seems to have moved so far in the opposite direction that no reversal of course is now open to it.

Taking the checkered pattern as the earlier one, the various conditions of checkers and bars in rock pigeons, domestic races, and, indeed, in all the wild pigeons, become almost self-explanatory. We could not explain satisfactorily how just two bars could arise *de novo* in one species, three in other, twelve in another, and so on. The repetition of *de novo* origins would become ever more incredible. Making phylogeny our guide as to the starting-point, we find it comparatively easy to thread our way through the maze of patterns existing among five hundred or more species of pigeons, and even to trace affinities farther back in the bird world.

The orthogenetic process is the primary and fundamental one. In its course we find unlimited opportunities for the play of natural selection, escape the great difficulty of in-

cipient stages, and readily understand why we find so many conditions arising and persisting without any direct help of selection.

Charles Darwin.

"As natural selection acts solely by accumulating slight, successive, favorable variations, it can produce no great or sudden modification." *Origin of Species*, ch. xiv, p. 421.

"Slight individual differences, however, suffice for the work, and are probably the sole differences which are effective in the production of new species." *Animals and Plants*, vol. II, ch. xx, p. 233.

"As modern geology has almost banished such views as the excavation of a great valley by a single diluvial wave, so will natural selection, if it be a true principle, banish the belief of the continued creation of new organic beings, *or of any great and sudden modification of their structure.*" *Origin of Species*, ch. iv, p. 98.

August Weismann.

"The simultaneous modification of numerous cofunctioning parts, in essentially different ways, yet in harmonious functional relations, points conclusively to the fact that *something is still wanting to the selection of Darwin and Wallace.*" *Germinal Selection*, p. 22.

"We know of only one natural principle of explanation for adaptation, that of selection." *Ibid.*, p. 61.

"The three principal stages of selection; that of *personal selection*, as held by Darwin and Wallace; that of *histonal selection*, as upheld by Wilhelm Roux in the form of a 'Struggle of the Parts;' and finally, that of *germinal selection*, the existence of which I have endeavored to establish—these are the factors that coöperate to maintain the forms of life constantly capable of life." *Ibid.*, p. 60.

"The harmony of the direction of variation with the requirements of the conditions of life is the riddle to be solved. *The degree of the adaptation which a part possesses itself determines the direction of variation of that part.*" *Ibid.*, p. 54.

"*When a determinant has assumed a certain variation-direction it will follow it up of itself, and selection can do nothing more than secure it a free course by setting aside variations in other directions by means of the elimination of those that exhibit them.*" *Evolution Theory*, vol. II, p. 123.

Carl von Nägeli.

"Between the *theory of selection and that of direct causation*, there is, apparently, only a little difference, since, according to the latter, the present condition of the organic world would likewise result from individual variation and elimination. But these two processes [selection and direct causation] differ fundamentally in their causal import. According to Darwin, variation is the germinating factor, selection the directing and regulating factor; according to my view, variation is at once both the germinating and the directing factor. According to Darwin, selection is indispensable; without it there could be no progression, and organisms would remain in the same condition as at the beginning. In my opinion, competition simply removes what is less capable of existence, but it is wholly without influence in bringing to pass anything more perfect or better adapted." *Theorie der Abstammungslehre*, p. 285.

"The fortuitous or directionless variation of individuals would be conceivable, if it were conditioned by external influences (food, temperature, light, electricity, gravitation); for, as these causes obviously cannot be brought into any definite relation to the more or less complex organization, they must effect sometimes a positive, sometimes a negative, step. If, however, the causes of variation are internal, in the constitution of the substance, then the matter stands otherwise. In this case *the determinate organization of the substance must exercise a restricting influence upon its own variation;* and this influence, as development begins at the lowest point, can only take effect in an upward direction." *Abstammungslehre*, p. 12.

"Individuals transmit to their offspring the tendency to be like themselves, but the offspring are not perfectly like the parents. *The tendency to variation must, therefore, also be transmitted.* A primordium, if all conditions are favorable, must be able to develop ever farther in a series of generations, as a capital enlarges to which interest is added annually; for each generation inherits from the preceding not only the possibility to realize the capital, but also the possibility to add the interest." *Individuality in Nature*, 1856.

Hugo de Vries.

"According to the theory of mutation, species have not arisen through gradual selection continued for hundreds of thousands of years, but by steps, through sudden though small transmutations. In contrast with variations, which are changes advancing in a

linear direction, the transformations to be called mutations diverge in new directions. They take place, then, so far as experience goes, without definite direction, *i. e.*, in various directions." *Die Mutationstheorie*, vol. I, p. 150.

RELATIONS OF BACTERIOLOGY TO OTHER SCIENCES

BY EDWIN OAKES JORDAN

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It is possibly a contemporary delusion that we are living in a period of unexampled mental activity. The life of the intrepid modern scholar affords opportunity for self-deception. If one becomes a member of a sufficient number of learned and quasi-learned societies, and attends committee meetings for an adequate variety of purposes, the impression of profitable intellectual endeavor may be prematurely acquired. There is much, however, to account for the prevailing sensation of breathless advance. The physiologic and psychologic accompaniments of a breakneck pace are not altogether lacking in the modern world, and there are bacteriologists, in particular, who will lend a credent ear to affirmations of the rapidity of scientific progress. However this may be, few can question that the development of the science of bacteriology has been marked by an unusual tempo. To those who have followed this development closely, discovery has trod upon the heels of discovery in bewildering succession. The scant thirty years of its his-

tory have been crowded with feverish activities, which have found their best justification in the results accomplished. At present the science touches nearly many human interests, and sustains manifold and far-reaching relations to the whole body of natural knowledge. It is no matter for surprise that such should be the case with a science that owes its birth to a chemist, that concerns itself with microscopic organisms belonging both to the plant and animal kingdoms, and that extends its ramifying branches into the regions of medicine, hygiene, and the industrial arts.

In several respects the history of bacteriology might be held to epitomize that of the other natural sciences, or of the living organism itself. Advance in complexity of structure entails greater complexity of relations and adjustment; maturity has more extensive connotations than youth. Bacteriology is a relatively youthful branch of the stream of knowledge, but in late years it has perceptibly widened its banks. It has even encroached upon certain neighboring sciences. Modern physiolography uses the term *piracy* to designate the capture by one stream of that portion of a water-shed legitimately belonging to another stream. In the same way, one natural science, owing to peculiarities in its subject-matter, in its evolutionary history, or in the tools with which it works, may enter upon a piratic career, and appropriate territory which for various reasons has remained unexploited by the science to which topographically it may seem to belong. This annexation of neighboring fields has been not uncommon among the natural sciences, and bacteriology has not shown itself free from the general tendency. A notorious instance of piratic conduct on the part of bacteriology is the virtual appropriation of the whole field of microbiology. Perhaps most familiar in this connection are the discoveries concerning the life-histories of various microscopic animal parasites. The tracing-out of the rela-

tions between parasites and hosts in Texas fever, malaria, and dysentery has by no means been exclusively or even largely the work of zoölogists. On the contrary, it is well known that much of the most important work in this direction has been carried out by bacteriologists, and that the literature on these topics is chiefly to be found in the technical bacteriologic journals. A recent instance of this tendency is the renewed study of the remarkable protozoa called trypanosomes, which has in large part been undertaken by bacteriologists and by bacteriologic methods. Perhaps the most notable triumph yet accomplished in this field is the successful cultivation of these pathogenic protozoa outside of the animal body, a feat which has been achieved by one of the foremost American bacteriologists. The exploitation of zoölogic territory by bacteriologic workers is one of the many instances of successful borderland invasion, and, like the Louisiana Purchase, illustrates the impotence of territorial lines to prevent natural expansion. Many reciprocal piratic inroads among the sciences are due to the acquisition by one science of new tools which, when workers become generally acquainted with their use, are found to be applicable to other problems in other fields. Bacteriologic technique is one of these efficient tools the possession of which conduces to piracy; it can, however, never be forgotten that bacteriology itself owes its powerful equipment to a study of spontaneous generation which was undertaken primarily for the interest felt in its philosophic bearings.

Bacteriology stands in close relation to at least four other more or less defined fields of natural knowledge; to medicine, to hygiene, to various agricultural and industrial operations and pursuits, and to biology proper. Bacteriology, as has been often said, is the youngest of the biologic sciences, and for this reason has as yet contributed relatively little to the enrichment of the parent science. Morphologically

the bacterial cell is so small and so simple as to offer many problems of surpassing interest, but of great difficulty. The question as to whether a bacterium is a cell without a nucleus, or a free nucleus without any cytoplasm, or a cell constituted in the main like those of the higher forms of life, has, to be sure, been practically settled in favor of the latter view. But there are other debated and debatable morphologic questions to which up to the present no satisfactory answer has been given, and to which our current microchemic methods are perhaps unlikely to afford any solution. On the physiologic side the achievement of bacteriology in behalf of general biology have as yet been far from commensurate with its potentiality. This may be partly because of its temporary engrossment in other seductive lines of research, partly because of the lack of workers adequately trained in bacteriologic methods and at the same time possessed of an appreciation of purely biologic data. It may be justly urged that a rich harvest of fundamental physiologic facts waits here for the competent investigator.

There is no need to dwell in detail upon the manifold practical applications of bacteriology to the arts and industries. Particularly in agriculture and kindred occupations have the advances in bacteriology been immediately and intelligently utilized to bring forth in turn new facts and unveil new problems. The processes of cream-ripening and vinegar-making, the phenomena of nitrification, of denitrification and nitrogen fixation, the modes of causation of certain diseases of domestic plants and animals, have all been elucidated in large measure by bacteriologic workers. A new division of technologic science, dealing with the bacteriology of the soil, of the dairy, and of the barnyard, of the tan-pit and the canning-factory, has already assumed economic and scientific importance.

It is often a temptation to distinguish radically between

pure science and applied science and to look upon the latter as unworthy the attention of the philosophically minded. True science can admit of no such distinction. Nothing in nature is alien to her. She can never forget that some of the most fruitful of scientific theories have been the outcome of the search for the utilitarian. Man's knowledge of the universe may be furthered in various ways. It is well known that the work of Pasteur was particularly characterized by applications to the problems of pure science of knowledge acquired in the study of the practical. One thing plays into the hands of another in wholly unexpected fashion. An attempt to improve the quality of beer gives birth to the germ theory of fermentation, and this in turn to the germ theory of disease; the chemistry of carbon compounds leads to the discovery of the anilin dyes, and these same anilin dyes have made possible the development of microchemic technique and thrown open spacious avenues for experiment and speculation; the attempt to obtain a standard for diphtheria anti-toxin has resulted not only in the achievement of the immediate practical end, but in the discovery of unexpected theoretic considerations which have dominated the progress of an important branch of scientific medicine during the last five years. It will not be a hopeful sign for the advancement of science when the worker in pure science ceases to concern himself with the problems or avail himself of the facilities afforded by the more eminently utilitarian aspects of natural knowledge.

In the quarter-century of its history, bacteriology has sustained close and mutually advantageous relations with the science of medicine. This has been the scene at once of its greatest endeavors and of its greatest triumphs. To recount these would be superfluous. There is hardly an hypothesis in scientific medicine that has not been freshened and modified, hardly a procedure in practice that has not

been influenced by bacteriologic conceptions. The experimental method in particular has been given new support and received brilliant justification. Experimental pathology and experimental pharmacology practically owe their existence to the methods and example of bacteriology. The security afforded by aseptic surgery has made possible physiologic exploits that could not otherwise have been dreamed of, a pregnant illustration of the way in which applied science may directly further the advance of pure science. Conspicuous as these achievements of bacteriology have been, it cannot be truly said that the field is exhausted. There is hardly an infectious disease of known or unknown origin that does not still harbor many obscurities. Some of the most difficult problems that medicine has to face are connected with the variation and adaptation of pathogenic bacteria. The phenomena of immunity, certainly among the most complicated and important that human ingenuity has ever set itself to unravel, still await their full description and interpretation. The study of the ultramicroscopic, or perhaps more correctly the filterable viruses, is being prosecuted with great energy and in a sanguine spirit. The extension of bacteriologic method into the field of protozoön pathology has been already referred to, and constitutes one of the latest and most hopeful developments in the study of the infectious diseases. Medicine, perhaps more than any other department of human knowledge, is most indebted to and maintains the most intimate relations with the science of bacteriology.

At the present time the relations of bacteriology to public hygiene and preventive medicine seem to me of particular importance, and it is upon this theme that I wish chiefly to dwell. Personal hygiene is not necessarily pertinent to this topic, but falls rather into the same province with the healing art. Matters of diet, of clothing, of exercise, of mental

attitude, affect the individual, and contribute more or less largely to his welfare. But except in so far as the individual is always of moment to the community, they do not affect the larger problems of public hygiene. The pathologic changes that take place in the tissues of the diseased organism and the methods that must be employed to combat the inroads of disease in the body of the individual patient must for a long time to come remain questions of supreme importance to the human race. But over and above the treatment and cure of the diseased individual, and the investigation of the processes that interfere with the proper physiologic activities of the individual organism, rises the larger and more far-reaching question of the prevention of disease.

Racial and community hygiene are but just beginning to be recognized as fields for definite endeavor. The project may seem vast, but the end in view is undoubtedly the promised land. More and more will the problems of curing an individual patient of a specific malady become subordinated to the problem of protection. More and more will scientific medicine occupy itself with measures directed to the avoidance of disease rather than to its eradication.

Whatever else may be said of it, this is certainly the age of deliberate scrutiny of origins and destiny. Man no longer closes his eyes to the possibilities of future evolution or to those of racial amelioration. If we are to remain to a large extent under the sway of our environment, we can at least alter that environment advantageously at many points. We are no longer content to let things as we see them remain as they are. On the surface the wider relations of disease have often seemed of little significance, as, before Darwin, the so-called fortuitous variations in plants and animals were considered as simple annoyances to the classifier; the causes of this variation were deemed hardly worth investigation.

The rise and fall of plagues and pestilences have been readily attributed to the caprices of the *genius epidemicus,* and it has sometimes been thought idle to ascribe recurrent waves of infection to anything but "the natural order." Another phase, entered upon later, and from which we have not yet entirely emerged, possesses its own peculiar perils. In meditating on the cosmos, the agile mind is always tempted to fill in the gaps of knowledge with closely knit reasonings or fantastic imagery. The imaginative man of science still frequently finds himself beset with the temptation to erect an unverifiable hypothesis into a dogma and defend it against all comers. It is now fortunately a truism that a more humdrum and plodding course has proved of greater efficacy in advancing natural knowledge. Theories that stimulate to renewed observation and experiment have been of the greatest service, but unverifiable speculations have often been a barrier to further advancement. Metaphysics tempered with polemic is not science, whatever be its allurements.

If the attainment of a rational position in public hygiene, community hygiene, or preventive medicine must, then, be regarded as the main objective point in the campaign against disease, it follows that the part played by bacteriology in this advance will be an important one. The relations of bacteriology to public hygiene are fundamental. The etiology of many of the most widespread and common diseases that afflict mankind is intelligent only through the medium of bacteriologic data. The modes of ingress of the invading micro-organisms, the manner of persistence of the micro-organism in nature, the original source of the infectious material, and all the varied possibilities of transmission and infection can be apprehended only through the prosecution of detailed bacteriologic studies. It is only by this means that the weak point in the chain of causation can

be detected and the integrity of the vicious circle attacked. Success will inevitably depend upon a thorough understanding of the circumstances governing and accompanying the initiation and consummation of the disease process. Yellow fever cannot be suppressed by burning sulphur or by enforcing a shot-gun quarantine; the bubonic plague is not to be combated by denying its existence.

In the warfare against the infectious diseases a rational public hygiene is ready to avoid the mistake of beating the air. A preliminary survey of the possibilities reveals several distinct types of disease; those that are practically extinct or far on the road to extinction in civilized communities, those that remain stationary, or decline but slightly, and those that show a more or less consistent increase. The economy of energy would suggest that it is not a far-sighted policy for public hygiene to focus its endeavors exclusively upon those diseases that are yielding naturally before the march of civilization. The conditions under which civilized peoples live to-day are in themselves sufficient to render the foothold of many infectious diseases most precarious. What nation now fears that typhus fever will become a national scourge, or who looks to see the citizens of London driven into the fields by the Black Death? It is of course true that the continuance of this immunity can be secured only by unremitting watchfulness, although so long as existing conditions of civilized life are maintained, the recurrence of great epidemics may be relatively remote. The pestilences that once stalked boldly through the land slaying their ten thousands are now become as midnight prowlers seeking to slip in at some unguarded door within which lie the young and the ignorant. Already some once-dreaded maladies have become so rare as to rank as medical curiosities, and their ultimate annihilation seems assured.

There are other diseases, however, that civilized life, or at

least modern life, appears to leave substantially unchecked, and some that it even fosters. These may be considered as shining marks for the modern hygienist. The scale between hygienic gain and loss is always in unstable equilibrium. There is no such thing as consistent improvement all along the line. As Amiel wrote in his journal, "In 1000 things we advance, in 999 we fall behind; this is progress." It is almost a biologic axiom that progress in one particular entails loss in others. To maintain the efficiency of all parts of the complex of civilization calls for eternal vigilance. It may be that while we are waxing complacent over the fact that the opportunities for infection with certain parasites are diminishing, and that other parasites are gradually losing what we vaguely denominate as their virulence, unforeseen and greater evils are raising their heads. The increasing exemption from certain diseases will itself lead to an increased prevalence of others as diversely vulnerable age groups are formed. In general, it will occur that the diseases peculiar to the advanced age groups will increase as the diseases of childhood and youth succumb to hygienic measures. A different age distribution of the population will bring in its train new problems of preventive medicine, which must be successfully solved if the issue is to be fairly met.

There are not lacking instances of a dawning consciousness on the part of mankind that the proper development of public hygiene involves a far more comprehensive view of its relations than has hitherto been taken. The study of tuberculosis is being approached by methods of unexampled broadness. We are just beginning to recognize the way in which the roots of this destructive malady are well-nigh inextricably interwoven with the whole social fabric. Bacteriologic, architectural, and economic data are all levied upon for contribution to our knowledge of what is univer-

sally recognized as one of the most important of all human diseases. Here, as elswhere, the care and cure of the infected individual still looms large, but beyond and above this is beginning to be placed the prevention of infection, the drying-up of the stream at its source. That for this heavy task public hygiene will require the aid of many workers in many different fields is abundantly evident. For all of them, however, bacteriology must furnish the only definite point of view. In the full consideration of the "exciting causes," the tubercle bacillus can never be allowed to drop into the background. Given foul air, insufficient food, inhalation of dust, excessive and exhaustive labor, and the other deplorable accompaniments of modern industrialism, and it still must be constantly kept in mind that without the tubercle bacillus these predisposing causes would never result in a single case of tuberculosis. On the other hand, without these contributing factors the tubercle bacillus would almost sink to the level of the negligible "non-pathogenic organism." Witness the impotence of the bacillus to produce infection, or even maintain itself, in the tissues of those individuals able to live an outdoor life.

It is evident that in the case of tuberculosis the forces of civilization are on the whole working for its extinction rather than for its perpetuation. The available statistics demonstrate that before the modern movement for the suppression of the disease began, and, in fact, even before the discovery of the tubercle bacillus, pulmonary tuberculosis was already on the decline in widely separated parts of the world,—in London, in Boston, and in Chicago.[1] It is, perhaps, significant that pulmonary tuberculosis is now one of the tenement-house problems, and that as such it occupies a

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[1] Biggs, N. M., *The Administrative Control of Tuberculosis, Medical News*, 84, p. 337, 1904.

Vital Statistics of the City of Chicago for the years 1899-1903, *inclusive*, Chicago, 1904.

strictly delimited field. As yet the campaign against tuberculosis has been a desultory one, waged by a few enthusiasts without adequate material or moral support on the part of the community at large, but signs are multiplying that this condition will be a transient phase. The comparative absence of intelligent, systematic endeavor for the suppression of disease is certainly a curious phenomenon in an age of otherwise extensive coördination and organized action. The executive talents and restless energy lavished on commercial, industrial, and engineering projects may some day be turned to devising and carrying out hygienic measures. If it were necessary to find an argument in the economic value of human life, it would be readily forthcoming. The recent movements for the study and suppression of tuberculosis mark one of the first attempts to apply bacteriologic knowledge in a determined and radical way to a problem of public hygiene. As regards the ultimate extinction of tuberculosis, there may be more or less groping after ways and means, but there need be no misconception as to the scope of the problem.

There are other fields in which a similar mode of procedure based on ascertained bacteriologic facts and principles has been indicated and is being at least in part carried out. In typhoid fever the evidence from epidemiology has long pointed unmistakably to drinking-water as being the chief vehicle of infection, and the first step toward suppression of this disease has been already taken in most civilized countries. The last half of the nineteenth century witnessed an improvement in the sanitary quality of public water-supplies which has diminished perceptibly the death-rate from typhoid fever. This change has been in part effected by the introduction of water from unpolluted sources, in part by the installation of sand filters. To cite a few well-known cases: For five years before the introduction of a filtered

water, the annual typhoid fever death-rate in Zurich, Switzerland, averaged 76; in the five years following the change it averaged 10. In Hamburg, Germany, for a corresponding period before filtration, the typhoid death-rate was 47; after the change it fell to 7. In Lawrence, Massachusetts, under similar conditions the typhoid rate was reduced from 121 to 26, and in Albany, New York, from 104 to 38. A similar effect has been noticed where an impure water has been replaced by water from unpolluted sources In Vienna, Austria, the abandonment of the River Danube as a source of supply in favor of a ground water diminished the typhoid fever death-rate from over 100 to about 6. In the United States the city of Lowell not long ago exchanged the polluted water of the Merrimac River for a ground water-supply, with the result that the typhoid fever death-rate was reduced from 97 to 21. In spite of these remarkable facts, there has been a lethargic slowness in profiting by the lessons that they teach. Many communities have remained to this day unobservant and negligent, and especially in the United States, the condition of the average public water-supply demands radical reform. A method that has not only reduced the deaths from typhoid fever by about 75 per cent., but has also reduced the number of cases proportionately, is worthy of universal adoption. If the fatality in all cases of typhoid fever was diminished, say from 12 per 100 cases to 3, by the use of a new drug or an antitoxin, the world would ring with the discovery. The introduction of a pure water-supply has achieved an analogous reduction in the death-rate, and confers further the enormous benefit of preventing the occurrence of a similar proportion of cases.[1] In the city of Albany, New York, the annual number of deaths from typhoid fever prior to the installation of a filter-plant aver-

[1] Jordan, E. O., *The Purification of Water Supplies by Slow Sand Filtration, Journal of the American Medical Association,* 1903, p. 850.

aged 89 during a ten-year period; in 1902 there were but 18 deaths from this cause, representing a diminution not only of 71 deaths, but of over 700 cases.

Important as is the function of a pure water-supply in preventing typhoid fever, it is now clear that public hygiene cannot stop here. In some countries, as in Germany, for example, where the larger cities and towns are supplied in the main with water of a highly satisfactory character, there still remains a notable residue of cases of typhoid fever. These, we know, are due to contact infection, to contamination of raw foods, such as milk, oysters, and the like, to the conveyance of the specific germ on the bodies of flies, and to similar modes of dissemination.[1] It is a fact full of significance that the existence of these various modes of spread is recognized, that they are held to be matters of public concern, and that preventive measures are being instituted under expert bacteriologic control for suppressing the existing sources of infection. One of the most difficult problems in this campaign lies in the prompt recognition and rigorous supervision of the mild and obscure cases. It may be comparatively simple to isolate and disinfect with thoroughness in the franker types of the disease, but it is not clear that the danger is most critical on this side. The application of searching and delicate bacteriologic tests is often necessary to determine the suitable mode of action. The dependence of public hygiene upon bacteriologic data and methods has rarely been better exemplified.

The vigorous warfare that is being waged against malaria in many tropical countries affords a further and striking

[1] Schuder, *Zur Aetiologie des Typhus*, *Zeit. f. Hyg.*, 38, p. 343, 1901.

Hutchinson, R. H., and Wheeler, A. W., *An Epidemic of Typhoid Fever due to Impure Ice*, *American Journal of Medical Science*, 126, p. 680, 1903.

Ficker, M., *Typhus und Fliegen*, *Archiv. f. Hyg.*, 46, p. 274, 1903.

Hamilton, A., *The Fly as a Carrier of Typhoid*, *Journal of the American Medical Association*, p. 577, 1903.

Newman, G. *Channels of Typhoid Infection in London*, *Practitioner*, 72, p. 55, 1904.

illustration of the utilization of existing resources for the avoidance of specific infection.[1] It is hardly necessary to reiterate the obvious truth that malaria constitutes the chief and, perhaps, the only serious obstacle to the colonization of the tropics by the white races. Political and economic questions of the gravest import to mankind are bound up with the fortunes of a protozoön and a mosquito. The complex life-cycle of the malarial parasite offers an unusual number of points of attack. As is well known, several distinct views are current as to the best way of interrupting the continuity of transfer between man and the mosquito. It is conceivable that by the destruction of the malarial parasite within the body of man, the supply of parasites for the mosquito may be cut off and the circle broken at this point. If the mosquitoes are prevented from becoming infected, man is safe. It is claimed by the adherents of one school that this method has proved very effective in certain localities where it has been systematically employed. The extermination of the parasite in the blood of man by the administration of quinine certainly constitutes an important weapon in the armory of public hygiene, whether or not it prove to be the most efficient one or the most economic in execution. In this same category are to be put the attempts to prevent the infection of the mosquito by guarding malarial patients against the bite of *Anopheles*. It is obvious that this plan may often be difficult of execution, because of the impossibility of exercising efficient control over the movements of individuals suffering from latent or recurrent infection.

A second possibility consists in the general protection against mosquito bite of all persons dwelling in infected regions. The pestiferous insect may beat its wings in vain against the windows of a mosquito-proof building; if it

[1] *Die Bekampfung des Malaria* (Koch, R, und Ollmig), *Die Malariabekampfung in Brioni* (Frosch, P.), *in Puntacroce* (Bludau), *in der Maremma Toscana* (Gosio, B.), *etc., Zeit. f. Hyg.*, 43, 1903, Heft. 1.

cannot come near enough to the human being to inject the contents of its poisoned salivary glands, no single case of malaria will result. In parts of Italy, it is said, this mode of prevention has been practiced with brilliant success in protecting railway employees, forced by the exigencies of their calling to reside in highly malarious localities.[1]

A third point of attack is presented in the possibility of destroying or at least arresting the propagation of the insect host of the malarial parasite. The extermination of a number of species belonging to a widely distributed and abundant insect genus may seem in itself a gigantic task to undertake. Remembering the ambiguous success that has attended the efforts of the human race to combat the ravages of certain insects injurious to agriculture, it is not easy to be sanguine concerning the speedy extinction of *Anopheles*. It is noteworthy that the most considerable triumphs attained along economic lines have been effected by the utilization of the natural enemies of the noxious forms. Efficient foes of *Anopheles* have so far not been discovered. There is no question, however, that in definite localities the numbers of individual mosquitoes belonging to malaria-bearing species may be enormously diminished by the destruction of the breeding-pools. The labors, in this direction, of English health officials in various parts of the world, have been rewarded by a decisive decrease in the prevalence of malaria.[2]

It will not escape remark that the effect of any one or of all of these protective measures is cumulative. A diminution in the number of mosquitoes, or in the number of persons harboring the malarial protozoön in their blood, or in the number of infected or non-infected individuals bitten by

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[1] Celli, A., *La Malaria in Italia durante il* 1902, *Annali d' Igiene sperimentali*, 13, p. 307, 1903.

La Société pour les études de la Malaria, Archives italiennes de Biologie (1898-1903), 39, p. 427, 1903.

[2] Ross, R., *Report on Malaria at Ismailia and Suez.* Liverpool School of Tropical Medicine, Mem. 9, 1903.

mosquitoes, will inevitably produce a lessening in the amount of malaria in a given region. This will in turn diminish the opportunities for mosquitoes to become infected, and will at least put a check upon indefinite extension of the disease. It is significant that a high degree of success apparently attends the enthusiastic and persistent application of any one of the measures instanced.

While malaria, typhoid fever, and tuberculosis are to-day fairly in the field of view of public hygiene, such is not the case with a host of other maladies. A beginning is made here and there, but the vast majority of the diseases that affect mankind still lack an intelligent and organized opposition. This is partly because of insufficient knowledge. At the present time the apparent increase in pneumonia presents an imperative field for research. It seems unlikely that the available modes of attacking this disease are to be exhausted with attempts to improve individual prophylaxis. A clear understanding of the tangled web of statistical, climatic, racial, bacteriologic, and hygienic questions that environ this urgent problem of public hygiene is likely to come only through renewed investigation of the phenomena. If it is true, as some conjecture on what seems insufficient evidence, that the virulence of the pneumoccecus is increasing, what is the bacteriologic strategy suited to the emergency? Or if it turn out that an increase in the number of victims to pneumonia is largely made up of those who have escaped an early death from tuberculosis, what procedure is indicated?

We cannot always take refuge from the consequences of inaction under the plea of ignorance. There are few, if any, instances in which public hygiene is utilizing to the full the knowledge that it might possess. Some responsibility rests upon those who are prosecuting bacteriologic studies to see that the bearings of their investigations are not over-

looked or neglected by those who are constituted the guardians of the public health. There is here no question of the sordid self-interest or commercial exploitation sometimes miscalled "practical application." In the long run the saving of life may play into the hands of the idealist. If John Keats had not died of pulmonary tuberculosis at the age of twenty-five, the modern world would be a different place for many persons. It is not possible to estimate the loss to literature, science, and art since the dawn of intellectual life which must be laid at the door of the infectious diseases. The relations of bacteriology to public hygiene, if properly appreciated and cultivated, will lead to an improvement in the conditions of life, which will enhance both the ideal and material welfare of the race, and will give greater assurance that each man shall complete his span of life and be able to do the work that is in him.

THE PROBLEMS IN HUMAN ANATOMY

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FOR the solution of the problems presented to him, the anatomist is by no means limited in his technique to the scalped or the microscope, but justly claims the right to use every aid to research which other departments of science are able to furnish. His position, therefore, in the scientific field is determined by the standpoint which he occupies and from which he regards animal structures, rather than by any special means and methods employed for their study.

By common consent anatomical material includes not only structures which may be easily dissected and studied with the unaided eye, but also those which tax the best powers of the microscope for their solution. But even within such wide limits the material that ordinarily comes to hand leaves much to be desired, and in elucidating this or that feature in the structures under examination, it is often found necessary to modify the physiological condition under which these structures have been working, in the hopes that their appearance may be altered thereby, and so be more readily understood.

Taken in a broad way, this is the reason why the data of pathology and experimental morphology are so important for the development of anatomical thought, helping as they do in the solution of the problems connected with the finer structure of the animal body, just as embryology and teratology illuminate the gross morphological relations in the adult.

I am quite aware that in making the foregoing statements I have suggested more modes of investigation than are at present used in connection with man. But the anatomy of the human body in adult life forms in itself so limited a field that no investigator can possibly confine himself to this portion alone, and there is every reason for here treating the subject in the larger way. As we see from the history of human anatomy, it was brought into the medical curriculum in response to the demands both of physiology and surgery, but gradually became most closely associated with the latter. For a long time its relative significance as a medical discipline was very great, because it represented the only real laboratory work which appeared in the training of the medical student. Indeed, a generation ago the exactness of anatomical methods was so lauded in comparison with the methods then commonly used in medicine, that anatomists came to scoff at the vagueness of their colleagues, while to-day, if we may be persuaded by some of our physiological friends, they have remained only to prey on the time of students who might be better employed. Although such a thrust may be readily parried, it is, nevertheless, necessary to admit that times are changed, and that as a laboratory exercise human anatomy is to-day outranked by several of the subjects in which the laboratory work permits a more precise formulation of problems and their more rapid and definite solution. However, it still retains, rightly enough, much of its former eminence.

Among the problems in human anatomy, there is, perhaps, none more important than the way in which it is to be presented to the five young gentlemen ranged around a subject in the somewhat trying atmosphere of the dissecting-room. Just what they may be expected to learn from such an experience would require some time to state. Certain it is that these beginning anatomists are almost all of them intending to become physicians, and some of them to become surgeons, and to this end they are building up a picture of the human body which will be useful to them in their profession. They are doing this by the aid of the best pedagogical means at their command, namely, the reinforcement of the ocular impressions by the contact and muscular sensations that come from the actual performance of the dissection itself. If previously they have had some experience in the dissection of the lower mammals, they will note at once the differences shown in the case of man, and if their embryology is at their command, it will be easy for them on suggestion or on their own initiative to appreciate how some of the peculiar relations between parts of the human body have been developed. Beyond this the information obtained is of the same order as that of the vocabulary of a language. The student gets a certain number of discrete pictures of the different parts of the body more or less clearly impressed upon his mind, and when he has occasion later to deal with these same parts, he has the advantage of finding himself in the presence of familiar structures. How far in this first experience the special groups of facts which are sometimes set apart under the head of surgical anatomy should be introduced, is a more or less open question. The present weight of opinion demands that they should still be kept by themselves. Nevertheless, while the anatomical experience of the average medical student should rest on a broad scientific back-

ground, he should at the same time have a distinct appreciation of the eminently practical value of the information he is expected to acquire.

The question at once arises how the monotony of long-continued dissection can be relieved, and the student maintained in a condition of sufficient receptivity to make the work really worth while; for the acquisition of vocabularies has never been counted as one of the greater pleasures of life. There are several legitimate devices: in the first place, if it is possible, for the student to have near at hand a microscope which may now and then be used for the examination of the different tissues as they appear in the cadaver. This cross-reference between the gross and microscopic appearance will serve to bring into close connection with one another two classes of facts which are often separated to their disadvantage, and to revive the histological pictures which should be incorporated in gross structures, but which in most cases remain forever apart from them. On the other hand, a search for anomalies or variations serves to give both a reality and purposefulness to the work and to make a student feel that in return for the large amount of time necessarily required for his anatomical training, he is, in some small measure at least, contributing to the science. It is unavoidable, this expenditure of time, and absolutely necessary that the student should do these things with his own hands, in order to obtain the three-dimensional impression of the structure with which he deals.

In this connection just a word as to the way in which the beginner may be aided in the comprehension of his work. The excellent diagrams and pictures which are now used to illustrate the best anatomical text-books carry us as far as that means of assistance can probably go. Pedagogical experience points strongly, however, to the superior value

of the three-dimensional model, and although such models are more difficult to collect, harder to care for, and require more space and caution in their use, they are so far superior to any other device, except an illustrative dissection itself, that the collection of them in connection with anatomical work becomes a moral obligation.

If we turn now to the wider uses which may be made of anatomical material as it usually appears in the dissecting-room, we find that a number of directors of laboratories have been utilizing this material for the accumulation of data in such a form that it may be later treated by statistical methods. Thus they have weighed and measured in different ways various parts of the cadaver, and in some cases determined the correlations between the organs or parts examined. It cannot be too strongly emphasized that the results thus obtained are to be used only with the full appreciation of the fact that the material ordinarily available for examination in the dissecting-room belongs in all countries to a social group which contains the highest percentage of poorly developed and atypical individuals. The conclusions, therefore, that can be drawn from the investigations of this material must always be weighted by its peculiar nature. To illustrate what is here meant by the peculiar character of this material, we may take as an instance the bearing of the results obtained from material of this sort on the problem of the brain-weight in the community at large. It must be admitted that the figures which we have at our command for this measurement are, with the exception of one short list, derived from the study of individuals belonging to the least fortunate class in the community, and it is not fair, therefore, to carry over these data and apply them directly to the average citizen who is of the normal type and moderately successful in the general struggle for existence. From what has been said, it is plain

that much of the work now being carried on in the dissecting-room comes very close to the lines which have been followed for years by the physical anthropologists; yet, because these have for the most part concerned themselves with the study of the skeleton, have limited their comparisons to the various races of men, and have developed no interest in surgery, they have for a long time stood apart, and only recently joined forces with the professional anatomists. This step has certainly been to the advantage of anatomy, and as one result of it, anatomical material not previously utilized will now be treated by statistical methods. But all the work to which reference has here been made is on the body after death. So manifest are the disadvantages arising from the conditions which are thus imposed that the necessity is felt on all sides of extending our observation as far as possible to the living individual. As an example of such an extension, we have the determination of the cranial capacity and brain-weight in the living subject which has resulted from the labor of Karl Pearson and his collaborators.[1] The methods which have been employed for this purpose are capable of giving as accurate results as are ordinarily obtained from post-mortem examinations, and, moreover, have the advantage of being applicable at any time to any group in the community which it is desired to investigate.

To redetermine, as far as possible, from studies on the living, all the relations which have been made out post-mortem, becomes a very immediate and important line of work.

But even under the general limitations which apply to the dissecting-room material, it is desirable to refine our knowledge of the human body by classifying the subjects according to race, and thereby bringing into relief the

[1] Pearson and collaborators, *Phil. Transactions* of the Royal Society, 1901.

slight anatomical differences that exist between the well-marked races of Europe and the races of other parts of the world. The history of anatomical differences due to sex lacks several chapters, and it is possible also to show the modifications of structure which come from the life-long pursuit of certain handicrafts which call for peculiar positions of the body or for the unusual exercise of certain muscles; as, for example, the anatomy of a shoemaker.[1]

Such results as the one last mentioned have a direct bearing on the modifications of the human form which may be introduced by peculiarities of daily life and work, and bring anatomy into connection with the problems of sociology; while, on the other hand, both lines of work are contributory to the broader questions of zoölogical relationship and susceptibility to modification.

Yet when we have gained all the information which the scalpel can give, there still remains the whole field of finer anatomy, the extent of which it is so difficult to appreciate.

While recognizing that the human body may be regarded as a composite, formed by the fitting together of the series of systems, and while, in some instances, we have a more or less accurate notion of the way such a system appears,—as, for instance, in the case of the skeleton,—yet a much better understanding of the relation of the soft parts would follow an attempt to extend this method of presentation, and to construct phantoms of the body in the terms of its several systems in some way which would show us the system in question as an opaque structure in a body otherwise transparent. This is, of course, the final aim of the various corrosion methods, or those which depend on injection or differential coloration of structures which may be viewed in three dimensions.

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[1] Lane, W. A., *Journal of Anatomy and Physiology*, vols. XXI and XXII, 1887 and 1888.

When the vascular, lymphatic, nervous, and glandular systems can be thus exhibited for the entire body, or for the larger divisions of it, it will be possible to see the human form transparently, and to see it whole; a feat difficult to accomplish, but worthy of earnest endeavor. The development of such phantoms should serve to make more impressive the familiar fact that in many organs and systems the total structure is built up by a more or less simple repetition of unit complexes, as, for example, the liver by the hepatic lobule, the bones by Haversian systems, and the spinal cord by the neural segments.

If we pass now from the consideration of the systems of tissues to that of their structural elements, we enter the domain of histology and cytology. Starting with the differentiation of the tissues by means of empirical staining methods, investigators have gradually come to appreciate the chemical processes which underlie the various color reactions, and as we know now, there already exist methods for determining in the tissues several of the chemical elements, such as iron, phosphorus, etc., to say nothing of the more or less satisfactory identification of complex organic bodies by means of definite reactions. This being the case, it is possible to imagine representations of the body built up on the basis of these microchemical reactions, representations which would show it in the terms of iron or in the terms of phosphorus, thus yielding us an image which might be compared with that obtained by aid of the spectroscope when the picture of the object is taken by means of one out of the several wave-lengths of light which come from it.

The contemplation of the multitudinous opportunities for investigation and comparison which appear within this field lead us to pause and inquire what is properly the purpose of all this anatomical work; for without a strong guiding

idea we are liable to repeat the errors of earlier generations, and merely accumulate observations, the bearing of which is so remote from the actual course of scientific progress that the investigations are mainly useful as a mental exercise for the individuals who conduct them. Anatomical results begin to have a real meaning only when correlated with physiology, and when we learn that a tissue with a certain structure is capable of performing given functions, we feel that we are really bringing our anatomy into touch with the life-processes. It is to aid in the accomplishment of this end that men devote their lives to anatomical work. With the variation that we find everywhere in organic structures, it should be and is possible to discover by comparison what variations in the structure of a tissue or a cell are accompanied by the best physiological responses. It is along this line that we must necessarily work in order to reach human life, either through medical practice or other avenues of approach, for in the end the object and purpose of all science is to ameliorate the unfavorable conditions which surround man, and in turn to produce a human individual more capable of resistance to disturbing influences, and better suited for the enjoyment of the world in which he lives.

Considering anatomical work with this thought in mind, the problems which it presents can be grouped according to their relative value and importance. The approach may be made from two sides. On the one hand it is, for example, extremely worth while to direct years of labor to the determination of the finer strucure of living substance, because the more closely we approximate to a correct view of that structure, the more readily will our anatomy and physiology run together, and the clearer will be the conception of the sort of structure which it will be most desirable to increase for the attainment of our final purpose.

On the other hand, if we follow the path from the grosser to the finer anatomy, we are led to inquire whether there is any one part or system of the human body which at the present moment is specially worthy of attention. When we say that the nervous system is such a part, I think that even those who are not engaged in the study of it will admit that there are some grounds for the statement. The peculiar feature which sets the nervous system apart is the fact that its enlargement, both in the animal series and during the development of the individual, is in a very special way accompanied by changes in its physiological and psychological reactions. To be sure, we think of it as built up fundamentally by the union of a series of segments, but the relationship established between these segments becomes ultimately so much more important than the constituent units that in the end we find ourselves working with a single system of enormous complexity, rather than a series of discrete units; a state of affairs which is not paralleled in any other tissue. In addition to this, the nervous system as a whole is *par excellence* the master system of the body, and as such, the reactions of the organism are very largely an expression of its complexity. Indeed, within the different classes of vertebrates, the various species may be regarded as compound bodies composed of four fundamental tissues, and a species could well be defined by the quantitative relations found to exist between the nervous, muscular, connective, and epithelial constituents. Working from this standpoint, Dubois,[1] the Dutch anatomist, stimulated by the work of Snell,[2] has brought forward evidence for the view that when, within the same order, several species of mammals similar in form, but differing in size, are compared with one another, the weight of the brain is found

[1] Dubois, *Archiv für Anthropologie*, 1898.
[2] Snell, *Archiv für Psychiatrie und Nervenkrankheiten*, 1892.

to be closely correlated with the extension of the body surface, and by inference with the development of the afferent system of neurones. This view would seem to imply that in these cases there is the same density of innervation of each unit-area of skin; but the correctness of this inference can only be determined by the careful numerical study of the afferent system of the animals compared. It will appear, however, that under the conditions imposed the relative weight of the brain depends upon the fact that each unit-area of skin, represented by the nerves which supply it, calls for a correlated addition of elements to the central system, and thus the increase in one part is followed by a corresponding increase in the other. When, however, the large and small individuals within the same species are compared, it is found that the increase in the brain-weight follows quite another law, and that in this latter case it is relatively much less marked than in the former. This result at once suggests that the mechanism of the increase is dissimilar in the two cases. For the solution of the problems that are raised by such investigations as those just cited, we need to employ quantitative methods, and on this topic a word is here in place.

Microscopic anatomy and histology, like all the sciences, have passed through a series of phases which are as necessarily a part of their history as birth, growth, and maturity are a part of the life-history of a mammal. The microscope in its early days enabled Schwann to propound the fruitful theory that the tissues were composed of cells. A preliminary survey showed that these cells were different in their form and arrangement in the different parts of the body, and a still more careful examination with the aid of various dyes or solutions altering the tissues in a differential way gave the basis for yet finer distinctions. This phase in the development of the science, however, may be fairly

compared with qualitative work in chemistry, where the object is to determine how many different substances are presented in the sample examined. Naturally, the next step is the introduction of quantitative methods, and we are, therefore, now using the methods of weighing, measuring, and counting for the purpose of rendering our notions more precise, and thereby facilitating accurate comparisons. When emphasizing this point, we do not, however, forget that hand in hand with this quantitative work the qualitative tests have been marvelously refined, and that these necessarily form the foundation for quantitative work, since all such work must deal with the elements or groups of elements which can be sharply defined, and the basis for their definition is given through qualitative studies. As progress is made along these lines, we appreciate more and more that it is of importance for us to know not only how much brain and how much spinal cord by weight normally belong to a given species of animal, but also the *quantitative relations* of the different groups and classes of elements which compose these parts. We are continually asking ourselves how far the range in gross weight of the central nervous system may be dependent on changes in the number of elements in the different divisions or localities, and how far dependent on the mere increase in the bulk of the individual units without any change either in their absolute number or relative size. Work along this line rests as we know on the neurone theory, that epoch-making generalization concerning the structure of the nervous system which was put forward by our honored colleague Professor Waldeyer.[1] Most of us are aware that, at the moment this theory is the subject of lively and voluminous discussion, and that Nissl,[2] for example, urges

[1] Waldeyer, *Deutsche medicinische Wochenschrift*, 1891.
[2] Nissl, *Die Neuronenlehre und ihre Anhänger*, 1903.

the inadequacy of the conception on the ground that it does not account for the gray substance in the strict sense.

No one can fail to appreciate the very great importance of the satisfactory conclusion of the present dispute, and earnestly desire that we may obtain conclusive evidence on points involved; but how ever the question of the gray matter may be settled, the enormous importance of the neurone conception, and the value of it for the purposes of the microscopic analysis of the nervous system, will remain untouched, while our quantitative determinations, applied to the neurone as we now understand it, will still have a permanent value.

Returning to the questions which are raised by the previously mentioned investigations of Dubois, we require in the first instance to determine the number of neurones connecting the skin with the central nervous system, and to see how this number varies in the different species of mammals similar in form but unlike in size. There is only one animal, the white rat, on which as yet such studies have been made, so that the whole field lies practically open. Should we be able to get good numerical evidence in favor of the view that under the conditions named above the afferent system could be taken as an index of the size of the brain, it would show us at once that in the laying-down of the nervous system certain proportions were rather rigidly observed, and bring us to the next step, namely, the determination of the influences which control those proportions and the possibility of effecting an alteration in them. In the mean time, there is every reason to prepare for the application of these results to man, and although the programme here is simple enough to state, it will involve great labor to carry it through.

So far as the numerical relations in man are concerned, we have, through the work of Dr. Helen Thompson[1] an

[1] Thompson, *Journal of Comparative Neurology*, 1899.

excellent estimate of the number of nerve-cell bodies in the human cortex, and through that of Dr. Ingbert,[1] a reliable count of the number of medullated nerve-fibres in the dorsal and ventral roots of the thirty-one pairs of spinal nerves of a man at maturity. It is easy to see, however, that we must get some notion of the amount of individual variation to which these relations are subject within the limits of one race and one sex before it is desirable to attempt to learn whether the difference in race or sex here plays an important rôle. It is to be anticipated, however, that the differences dependent upon race and sex will be comparatively slight, and especially so when contrasted with the differences which we may anticipate as existing between the adult and the child at birth. This aspect of the problem illustrates, in a concrete form, the sort of question which is raised by the anatomical study of the body during the period of growth. The embryologists have worked out the formation and early developmental history of the various organs and parts of the human body, but the study of the later fetal stages have been blocked by the scarcity of material, and the inconvenience of dealing with it. On the individual at birth, we have again more extensive observations, but for the period comprised between the first two years of life and the age of twenty our information is again scanty. The lower death-rate during this part of the life-cycle, as well as social influences, combine to keep material between these ages out of the dissecting-room. Here is an important part in the life-history of man which needs to be investigated along many lines, and during which it is most desirable to have record of the changes in the nervous system expressed in quantitative terms. In the general problem which is here under discussion, our next step would be to enumerate in man at birth the medullated nerve-fibres

[1] Ingbert, *Journal of Comparative Neurology*, 1903 and 1904.

in the roots of the spinal nerves. Such an enumeration will probably show us between birth and maturity a very large addition to the number of these fibres, but we still have to determine at what portion of the period, and according to what laws this addition takes place. At this point our observations on animals will assist us, and we should certainly look for the occurrence of greatest addition during the earlier part of the growing period.

Let us assume, then, that we have obtained results which show us the normal development of this portion of the nervous system between birth and maturity. These observations could be used as a standard. Once possessed of such a standard, we are prepared to determine variations in the nature of excesses or deficiencies, and in this instance the question of deficiencies is the one most easy to handle.

The studies of Dr. Hatai[1] on the partial starvation of white rats during the growing period show that very definite changes can be brought about in the nervous system when these animals are deprived of proteid food for several weeks. As a result of such treatment, the total weight of the nervous system is reduced much below that of the normal rat. Such a result, however, leaves two points still undetermined: (1) the general nature of the changes bringing about a diminution in weight, and (2) the parts of the system in which changes occur. In testing our animal material by quantitative methods, we should in the first instance direct attention to a possible decrease or arrest of growth in the afferent system of sensory nerves, and seek to determine whether the unfavorable conditions have not retarded the growth-process in this division of the nervous system. If the results of such observations are positive, we may expect to find a corresponding modification in man, when the human body during the period of

[1] Hatai, *American Journal of Physiology*, 1904.

growth is subjected to unfavorable conditions of a similar nature. As a matter of fact, such unfavorable conditions do exist in the crowded quarters of our larger cities, and it seems highly probable that we have there in progress examples of partial starvation quite comparable with the experiments conducted in the laboratory. Under these circumstances, it is important to discover in the case of our animals how far a subsequent return to normal food conditions will modify the anatomy of a nervous system which has been subjected to proteid starvation for some weeks. At present there are no observations which indicate whether or no recovery in the nervous system will take place, and it will probably require some time to reach a definite conclusion. The work necessary for a determination of the anatomical changes exhibited by the animals alone constitutes by no means a light task, since in order to obtain reliable results and to eliminate the factor of individual variation a series of individuals must be examined, and it requires a very definitely sustained interest to carry through the long line of enumerations necessary for such an investigation. The examination of the growth of the nervous system in animals subjected to definitely unfavorable conditions is, however, only one part of the work.

It will be necessary to contrast the changes there found with the effects of special feeding, care, and exercise in other groups, in order to see how far above the ordinary form the nervous system can be anatomically improved by any such treatment; and experiments in this direction are already being conducted by Dr. Slonaker. Of course, the results which have been obtained and may be obtained on the animals studied in this way should not be directly applied to the case of man, because it seems quite evident that the higher organization of man is responsible for his ability to resist to a remarkable degree the disturbing ef-

fects of an unfavorable environment. The impression is abroad that the reverse is the case, and that it is man who is more responsive to unfavorable surroundings. I believe, however, that this current view will prove to be incorrect, for the lower mammals at least, and that when we place such animals where the conditions for them are abnormal, their limited powers of adaptability lead them to be more seriously affected than are animals which are more complexly organized. If such is the case, variations of the same amount should not be expected to appear in man, but there is every reason to assume that the variations which do appear will be of the same general character, and that we might look for them in the human nervous system where we find them in that of the rat. When it is possible to see how the anatomy of the nervous system may be altered during the post-natal growth-period, we shall be prepared to take up the problem of how it may be improved during embryonic and fetal life, and how the actual number of potential neurones is determined and their relative distribution controlled, and this should lead ultimately to the attempt to breed animals with improved nervous systems in which we shall know the nature of the improvement in considerable detail.

It may be urged that putting the problems in this way indicates a greater interest in the application to physiology of the anatomical results than in the results themselves. But I take it that the interest of a machinist in building a machine is to make the parts for one that will go, and that no less honor is due him for his painstaking care in determining the construction of the different parts and their right relations, because at the end of the operation he has devised something capable of doing work. Similarly it is possible that a man's interest from day to day shall be absorbed in the technique of anatomical science,

and yet, it is nevertheless distinctly advantageous, if his anatomical observations bear on the performances of the living animal, and a final result is obtained which is the synthesis of research in two associated fields.

In drawing up the preceding outline, no one is more aware than the writer of the fact that problems connected with the nervous system have alone been considered. Without doubt those more interested in the other systems of the human body could duplicate for these the problems which have been suggested in connection with the nervous system, so that the account given above may be taken simply as an illustration of the sort of thing that seems worth doing. In presenting these illustrations it has been my purpose to indicate a standpoint from which the anatomical problems can be profitably regarded, and to draw attention to the use of quantitative methods in the study of anatomy, and especially as applied to the body during the period of active growth.

Yet perhaps the largest of our problems, and certainly one which appeals to all of us, is the ways and means for the solid advancement of our science. Alongside of the question of how we shall hand down to successive generations of students the facts already established, lies the still more fundamental problem of the best method of building-up the body of anatomical knowledge.

It is not my purpose to advocate as a means to this end the sharp separation of teaching from investigation. It is a rare man who can stand the strain of such a division, whether he chooses one or the other, and there is, moreover, much to be said for such an arrangement as will bring the average student into a laboratory where he can himself see how research work is conducted. Yet it would be possible to name institutions in which the relative amount of time required for teaching as compared with

that left free for investigation might with advantage be readjusted, and almost all of our educational institutions at the same time admittedly lack the funds and often the educational purpose, which would justify them in attempting to meet the various difficulties connected with anatomical investigations on a large scale. Yet no one questions the importance of striving for a more rapid advance. A response to this feeling finds its expression in the several research funds which are now available in this country and abroad for the endowment of investigation, and in the plan presented to the International Association of Academies, and, it should be added, largely due to the initiative of Professor Waldeyer, for the establishment in various countries of special institutes for the furtherance of research in embryology and neurology.

These two subjects were first selected owing to the peculiar difficulties of obtaining the needed material, and the great labor necessary to prepare the complete series of sections which are required in many cases. These conditions make it imperative that, if we would avoid large loss of labor and much vexation of spirit, the work in these lines should be coördinated, standards adopted, and the material of the laboratory, like the books of a library or the specimens in a museum, be available for the use of other investigators. Nothing, I believe, is further from the minds of those engaged in this plan than an attempt to produce anatomical results on a manufacturing scale. But the questions calling for solution in the fields here designated are so numerous that such an arrangement will merely mean a subdivision of labor in which each institute will take one of the larger problems and direct its main energies to the study of this, so conducting the work that it shall be correlated with that in progress elsewhere. The director of such an institute will be justified in extending his work

through assistants just as far as he can carry the details of the different researches in progress, and thus knit them into one piece for the education of himself and his colleagues. When we pass beyond this limit, admittedly subject to wide individual variation, there is little to be gained, but the evils of excessive production, should they arise, carry within themselves the means of their own correction.

This step, which is assuredly about to be taken, should enable us in the future to do things in anatomy not heretofore possible, and when, some years hence, there is another gathering of scientific men, with an aim and purpose similar to that of the present one, it is easy to predict that we shall be able to listen to a report on the important advances in anatomy arising from coördinated and coöperative work.

PROBLEMS OF PHYSIOLOGY OF THE PRESENT TIME

BY WILLIAM HENRY HOWELL

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MOST of the masters in physiology have attempted in one way or another to lay before their fellow craftsmen their ideas concerning the right methods to be used in physiology, its natural boundaries, and its future development. We read these utterances sometimes with admiration, sometimes with doubt, but always with interest, and also, alas, with disappointment. For it has not been given to any of our saints or prophets to pierce very far into the uncertain future, and one seeks in vain for a fundamental thought or principle which shall illuminate the mystery of life. Our greatest men have, in fact, been wise enough to teach us by example rather than by precept; the chief lesson that one may learn from their lives and writings is that we must continue to investigate, to observe, and to experiment, and that in this way only can sure progress be made toward the goal of which we all dream. The time seems not yet ripe for the master-mind to gather the scattered data and mold them into great generalizations or laws such as have been achieved in other sciences. We must, perhaps, admit that the philo-

sophical basis of physiology, its general principles and quantitative laws, have been borrowed in large part from other departments, and that the subject has not as yet fully repaid this indebtedness by contributions derived solely from its own resources. We have no names to which science as a whole owes as much as it does to Galileo, Lavoisier, Newton, Mayer and Joule, Darwin or Pasteur,[1] and since we may claim that our greatest physiologists rank with the first intellects of their age, their failure to penetrate farther into the causation of vital phenomena must be attributed to the intrinsic difficulties and complexity which the subject offers to the human mind. None of us can change this condition, and those who desire to forecast the future must be content, therefore, to view the subject from the standpoint of past experience and the history of other sciences whose field of work has presented apparently less formidable difficulties.

In what may be termed the golden period of physiology, that is, the latter two thirds of the nineteenth century, the period during which the subject became established definitively as an experimental science, the rich and abundant harvest of facts gathered by the first workers who adopted exclusively experimental methods awoke enthusiasm and brightest anticipations. The workers in physiology were animated by a confident belief that their science was on the highroad to a successful solution of the nature and properties of living matter. Now, however, at the beginning of the twentieth century, one hears frequently the voice of dissatisfaction and criticism. Although the workers are more numerous, and the methods and appliances are more complete, the harvest of facts is not so rich nor so significant. Therefore to many it would seem that the methods used

[1] While two of the names quoted have a right to be classed among physiologists (Lavoisier and Mayer), the contributions made by them which have been so fundamental to all sciences were in the departments of chemistry and physics.

are at fault; there is need at least for a new point of view. It requires but little reflection to become convinced that some of the implied or expressed criticism directed toward recent work in physiology is unjust and is founded upon a misconception of its true nature and development. I refer particularly to the belief so frequently expressed that much of the current investigation in physiology is sterile as regards its immediate applicability to practical medicine, and the further statement that the subject itself has become isolated in a measure from the other biological sciences.[1] I do not contest the accuracy of these statements, but both results must be regarded as a necessary outcome of the normal and healthy development of the science of physiology. The general history of physiology is known to us all; it is not necessary to enter into details. It arose out of medicine and developed in intimate relations with the study of anatomy. But even in its earliest history its most significant results were obtained by the use of the experimental method, and in the nineteenth century its separation from the purely observational sciences was clearly recognized. The establishment of physiology as an experimental science is usually attributed to Johannes Müller and his pupils or their contemporaries who fell under his influence. But as I read its history, its modern characteristics, whether for good or for evil, owe their origin as much to the French as to the German school. Johannes Müller himself was not preëminent as an experimenter,—he made use of anatomical rather than physiological methods; but his contemporary Magendie was a typical modern physiologist, and whatever may have been the extent of his personal influence during life, there can be no question that his methods of work and his points of view are the ones that were subsequently adopted in physiology.

[1] Meltzer, *Vitalism and Mechanism in Biology and Medicine, Science,* vol. XIX, p 18, 1904. Verworn, *Einleitung, Zeitschrift für Allgemeine Physiologie,* I, p. 1, 1902.

I am not concerned at present, however, with the attempt to estimate justly the relative influence of these great men and their pupils; the simple point that I wish to insist upon is that they established physiology as an experimental science, and pointed out that its most intimate relationship must be with the other experimental sciences of physics and chemistry. Physiology, said Bernard, is not a natural but an experimental science, and most recent writers have defined the subject as consisting essentially of the physics and chemistry of living matter. The two results spoken of above have followed as an inevitable outcome of this course of development. As an independent science, with specific problems of its own, physiology has naturally loosened its connections with the art of medicine. Formerly one of the handmaids of the noble art, it has been freed in a measure from this servitude, and although its results must always be of the greatest importance to the scientific side of medicine, it can no longer be expected to devote itself mainly to the immediate needs of the physician. The practical problems of medicine that can be studied by physiological methods have been undertaken less and less frequently by the physiologist proper; they have fallen to the hands of the pathologist and the clinician. Physiology does its part in this work by giving to such men the needful technique and training which have been developed by the study of its own problems, and the results obtained redound no less to the credit of physiology because the investigator concerned happens to be classified as a pathologist or clinician. All of the sciences are characterized by this mutual helpfulness; the methods and standpoints developed in one frequently give essential aid to the workers in a related science; and the full outcome of the labors of the narrow specialist cannot be justly estimated by the immediate results in his own department. The physiologist proper, the specialist in physiology,

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The International Congress of Arts and Science presents men renowned in almost every branch of Science, leading professors of the greatest institutions of learning, astronomers, surgeons, technologists, economists, pathologists, analogists, physicists—famous specialists and scientists from all quarters of the globe.

The present group includes a number of these celebrities. In the front row, from left to right, we have the full-length portraits of Prof. J. G. Hagen, S.J., of the Georgetown University, which was founded by the Jesuits in 1788; Dr. Carl Beck, Professor of Surgery in the New York Post-Graduate Medical School; Dr. Wilhelm Waldeyer, Professor of Anatomy, University of Berlin; Dr. Simon Newcomb, President of the Congress and Dean of American Scientists; Dr. Oscar Backlund, Astronomer of the Imperial Academy of Science, St. Petersburg; Dr. Ormond Stone, Professor of Astronomy, University of Virginia; and Dr. David Starr Jordan, President of Leland Stanford, Jr., University, in California. In the second row on the extreme left, we have the portrait of Dr. Benjamin Ide Wheeler, President of the University of California, and on the extreme right stands Dr. Eugen von Philippovich, Professor of Political Economy, University of Vienna.

must devote himself to the peculiar problems of his own subject. It cannot be otherwise, for who else is to attempt the solution of these problems? The practical interests of such work to medicine may seem to be remote, but it is hardly necessary to repeat the often-quoted injunction, founded upon past experience, that the solution of a special problem of a fundamental nature carries with it in the long run the most important practical results. The state of affairs in physiology is exactly similar to what has long been recognized as proper and natural in chemistry and physics. The chemical problems of practical medicine are not solved by the chemist, scarcely indeed by the physiological chemist. But those who undertake these problems avail themselves to the fullest of the knowledge and methods of chemistry, and without this aid their work would be impossible. In the same way physiology will continually aid in the immediate practical work of medicine, although those who designate themselves as physiologists may less and less frequently give their own hands to such work. We who are physiologists should not be lukewarm nor too critical in our attitude toward the work of the specialist. Those who undertake the solution of the problems of medicine find a large and sympathetic audience; their work wins quick recognition, and oftentimes substantial rewards; while those who attempt the more special and peculiar work of the science of physiology are not likely to attract the attention or the interest of physicians; they must look to their colleagues for encouragement and recognition. What has happened to physiology in this matter of its relation to medicine will eventually be true of the other medical sciences. The tendency is already well developed in the subject of anatomy. The specialist in this subject is no longer interested chiefly in the surgical or medical bearing of his problems; he has questions of his own that look toward

the understanding of the great laws of growth and development. Medicine should not wish to keep its children forever tied to its own apron-strings. In proportion as they develop normally and healthfully, they must look forward to an independent existence, and the great mother doubtless will find most honor and help from her offspring as they reach their maturity and contribute to her support otherwise than by immediate hand-service.

It has been inevitable also that the development of physiology as an experimental science should cause it to grow away from the other biological sciences. Anatomy and the morphological side of botany and zoölogy are observational sciences, and their methods vary widely from those employed in physiology. It is still true, of course, that purely anatomical work may furnish important data for physiological conclusions, for instance, in the physiology of the nervous system; yet the tendency of physiology is and has been, to depart from such methods, and there has become apparent an increasing lack of sympathy, a lessening of mutual understanding of each other's work between the anatomist and the physiologist. We cannot expect the old relationship to be renewed by a return of physiology to its ancient methods. On the contrary, if there is to be a restoration of the former close union, the advance must come from the side of anatomy. Many of the problems of this latter science will eventually call for the test of experiment, and even now an increasing number of its workers are occupying, as it were, a middle ground between the two subjects,—deriving their problems from the side of anatomy and their methods from the side of physiology. Through the influence of this band of workers it is possible that the two sciences may be brought more closely into touch with each other than has been the case for the last few decades. But while the bond between physiologist and biologist has

been less cordial than in former years physiology has found a compensation in the ever-increasing intimacy of its relationships with physics and chemistry. The physiologist looks more and more to chemistry, physics, and physical chemistry for suggestions and methods. How can it be otherwise, if the current statement be true that physiology in the long run has to explain the physics and chemistry of living matter? The truth of this point of view will be apparent to any one who will trace the development of physiology, and it is brought forcibly to the mind of every teacher of the subject when he attempts to direct the training of one who looks forward to a career as a specialist in physiology. I believe that every physiologist feels that the chief preparatory training in his subject should consist in a thorough grounding in physics and in chemistry. If many of the results of recent physiological investigations have not been as decisive as we could wish, is it not probable, nay, almost certain, that the fault lies not in the nature of the problems investigated, nor altogether in the character of the experimental methods employed, but in the inadequate training of the workers? If our investigators were better equipped in the matter of technical training, there would perhaps be less cause for complaint on the score of results, for in physiology, as in the other experimental sciences, the number of problems that may be studied by known methods is very large, one might almost say indefinitely large. We need in physiology not only the great experimenters like Ludwig and Bernard, men with an inborn spirit of curiosity and a talent for experimental inquiry, but also a large number of productive investigators whose capacity may be of a lower order, but whose training shall be complete enough to insure the acquisition of exact and positive results.

If, as I believe, every one will admit the correctness of the facts stated above regarding the tendency of modern physi-

ology to imitate closely the methods used in physical and chemical investigations, the only point to be considered in this connection is whether or not this tendency is premature. Is physiology, in fact, in a sufficiently developed state to employ the methods of the exact sciences? After all, most of the criticism regarding current physiological investigation seems to carry with it the implication that in great part at least the subject as yet is not prepared for the quantitative methods of the other experimental sciences. In considering this point much depends necessarily upon the meaning one gives to the term physical and chemical methods. If we restrict this term to purely physical or chemical studies of living matter in the cell or in the organism, the contention of those who are dissatisfied with the results of recent work is more readily understood, although, in my opinion, far from being justified. Dealing with a substance whose composition is very complex and unstable, and whose structure is not known, it is apparent that rapid progress cannot be expected and exact results cannot often be obtained even by the employment of accurate methods of research. Such work demands, as Ludwig expressed it, that we shall explain each phenomenon as a function of the conditions producing it, or, to use Mach's phraseology, as a function of those variables upon which it depends. It is necessary in such experiments that one condition or set of conditions be kept constant while another is varied in a known way. While this end is often attained in the study of the properties of dead matter, it seems entirely obvious that the complex and unstable living matter should offer much greater difficulty, and that the results obtained should be much less definite and conclusive. Hence the numerous investigations in physiology that lead to diverse and inconstant conclusions. Hence also the error into which falls the over-sanguine physiologist who imagines that he can borrow his method

from physics or chemistry and apply it forthwith to the successful study of the properties of living matter. Every one must grant that this kind of work represents the highest ideal of physiological investigation, an ideal toward which the science should endeavor to develop; but judging solely by the results obtained hitherto, one may be forced to admit that the acquisition of positive knowledge by these methods has been slow and uncertain. Such relatively simple problems as the elasticity of the living tissues, the hydrodynamics of the blood-flow, the electrical phenomena of the functional nerve-fibre, the chemical changes of the foodstuffs during digestion and absorption, the chemical changes of respiration and secretion, are still the subjects of apparently endless controversies. Few of the problems of this character that occupied the attention of our predecessors fifty years ago have been solved satisfactorily. In each generation certain conclusions are accepted and taught, but we are all aware how constantly our views are undergoing change, and how few are the facts that we may consider as definitively demonstrated. The writers of text-books are obliged to prepare frequent new editions not only for the purpose of adding new material, but of correcting the old. In fact, in respect to the exact methods of research, the state of physiology is not greatly different from that of physics or chemistry a century ago. Doubtless much of the work done by these methods is poorly done, or at least leads to no positive conclusions, owing to the intrinsic difficulties of the subject. But granting all this, it seems to me nevertheless that in this direction lies the path of greatest honor for those whose capacity and training mark them as leaders in the subject. We cannot seriously criticise this kind of work without surrendering all hope of the future of physiology. We can only justly criticise the lack of judgment in those who undertake it without sufficient preparatory training or knowledge of the subject.

If, on the other hand, by physical and chemical methods we understand the experimental method, whatever may be the character of its technique then the question suggested above becomes relatively simple. This, I believe, is the standpoint assumed by the founders of modern physiology, and this is the truth which they wished to emphasize when they claimed that physiology is essentially an experimental science which must develop along lines similar to those worked out in physics and chemistry. When Magendie completed the demonstration of the division of function between the anterior and the posterior roots of the spinal nerves, a distinction that had been assumed by Bell on anatomical grounds, he used the chemical and physical method; he stimulated each root, and thus arrived at a positive conclusion which could never have been reached except by the employment of the experimental method. And those observers like Langley, who in our own day are slowly unraveling the physiological mechanism of the so-called sympathetic or autonomic nervous system and are using experimental stimulation at every stage of the work, are also in this sense employing the physical and chemical method. From this point of view there is no room for criticism regarding the progress, past or future, of the science of physiology. Most of our advance in knowledge has been due to direct experimental inquiry, and the opportunities for further satisfactory work of the same character are lacking only to those who fail in the zeal or talent requisite to imagine and carry out experimental investigations. A recent writer[1] has said, "He who cannot discover and classify new facts in any branch of natural science after a few weeks or at most a few months, of industrious work must indeed be ignorant or unskilled." As regards experimental physiology, I can-

[1] Ostwald, *The Relations of Biology and the Neighboring Sciences*, University of California Publications, *Physiology*, I, p. 11, 1903.

not agree with this author in the implied simplicity of the task of discovery of new facts. I fancy that the unpublished history of the subject contains records of many investigations which were carried out by observers neither ignorant nor unskilled, but which failed to unearth any new facts. But this much seems to me to be certain, that in physiology at present there is abundant opportunity for every grade of investigation. The subject is not so far advanced that new facts of even the simplest kind are without value. That purely anatomical studies may have a profound influence upon physiological theories is illustrated in the most striking way by the history of the so-called neurone doctrine and by the modified views upon this subject that are beginning to be felt in consequence of the anatomical work of Apáthy, Nissl, Bethe, and others. For physiology, however, it is all-important that the ideas suggested from the anatomical side shall be verified and expanded by the experimental method. Bethe's experimental researches upon the degeneration and regeneration of peripheral nerve-fibers have added greatly to the significance of his anatomical work, and will insure the recognition of the importance of the newer ideas concerning the physiological mechanisms of the nervous system. While I agree most heartily with Verworn[1] that physiology should claim "vollständige Freiheit in der Wahl des Objekts und in der Wahl der Methoden," I find it necessary to supplement this demand by the restriction that the methods, to be physiological, must be experimental. This peculiarity constitutes the shibboleth that serves to distinguish the physiologist from his biological comrades. So long as any physiologist answers to this designation, he should be recognized as a worthy member of our guild. The tendency sometimes exhibited by our most active and prominent workers, to magnify the importance of their own, perhaps newer,

[1] *Loc. cit.*

methods, by contemptuous or despairing criticism of the methods employed by other workers, seems to me not only ungenerous and unjustifiable, but even positively injurious to the advancement of our science. There is opportunity for important results from all good methods whether old or new, and he whose training or opportunities enable him to do his best work along well-established lines need not be discouraged or diverted in his labors because newer modes are the sensation of the hour. Our greatest teachers have been characterized always by a large-minded sympathy for work of all kinds so long as it is well conceived and well executed.

In all the biological sciences there is an opportunity for physiological work. Hypotheses based upon anatomical facts call for the test of experiment, and the methods that suffice in the beginning may be relatively simple, so that little or no technical training is required for the work so far as the experimental side is concerned. The experimental zoölogist has entered upon such a field. For no good reason he has selected this designation, which seems to suggest the formation of a new specialty. As a matter of fact, experimental work upon animals is necessarily physiological, and the experimental zoölogist must look for his methods and implements to the science of physiology. Work of this kind has all the fascinations of pioneer life; it holds out the possibility of rich discovery, of unexpected finds, and will doubtless attract from physiology and from anatomy the adventurous spirits with large ideas, together with many who are simply dissatisfied with conditions as they are. I cannot, however, sympathize with those who, stirred by the results already reported, seem to feel that all of the energy and ability of our subject should be diverted to this kind of work. On the contrary, however important and attractive this work may be, it is distinctly not the best field for the trained specialist in physiology. There is a large domain

discovered by the pioneers of other times which needs development. Crude methods will not suffice for this work, and it constitutes the special field for the best-trained artisans in physiology. This most difficult and most fundamental work must be accomplished through the agency of the exact methods of physics and chemistry, and if those who have the requisite training are devoting themselves energetically to this duty, those of us who may lack the ability or special training for such complex undertakings should not be too critical of the results. In the nature of things the work of the pioneer is likely to bring greater glory and recognition to those who make a success of it, but the regions he opens must be subsequently explored and developed. Those who do this latter work are the ones who really determine the importance of each new discovery; they are the ones who ascertain for us whether it is a barren country that has been opened up, or one rich in the possibilities of wealth. This, as I see it, is the kind of work in which the great body of physiologists is actually engaged at present, and it is a kind of work in which the technical methods of physics and chemistry must be of increasing importance.

But whether physiological work is directed along purely physical or chemical lines, or is, to use a current designation, biological in character, so long as its experimental side is emphasized, it is pure physiology, and must, if pursued with energy and ability, contribute to the advancement of our science. This has been the line of development of modern physiology from the time when its founders first pointed out the inadequacy of observational methods and unsupported speculative reasoning. Those who were responsible for giving it this direction of growth felt that its future was thereby assured. "La physiologie," said Bernard,[1] "définitivement engagée dans la voie expérimentale, n'a plus

[1] Bernard, *De la physiologie générale*, Preface, Paris, 1872.

qu'á poursuivre sa marche." For a long time we have been advancing along this path, and it is only necessary to look back to realize the great progress that has been made. When we look forward, however, difficulties present themselves that have made some physiologists doubt whether after all the experimental way will lead us to the end that the science has in mind. The apparently insuperable obstacles continually obtruding themselves always alarm unduly some of our leaders. Fifteen years ago a well-known physiologist, who has himself done much valuable experimental work, exclaimed that our present methods of investigation had reached their limit.[1] "The smallest cell exhibits all the mysteries of life, and our present methods of its investigation have reached their limit." But in the brief period that has elapsed since that complaint was made, many additions of striking importance have been made to our knowledge, "with the help of chemistry, physics, and anatomy alone." Since that time the discovery of internal secretions has opened a new field of experimental work; the methods of physical chemistry have found a fruitful application in the problems of secretion and absorption; physiological chemistry has steadily added to our knowledge of the composition of the body; our conceptions of the influence and extent of the action of enzymes has been greatly broadened, and the whole subject of so-called biological reactions as illustrated by the acquisition of immunity toward foreign substances, has been added to our means of research.

Long ago Borelli and his followers, the iatro-physicists and iatro-chemists, had rightly conceived the method by means of which the problems of physiology should be approached, and if in the eighteenth century the workers in this subject became discouraged and forsook the narrow

[1] Bunge, *Physiological and Pathological Chemistry*, Introduction, English translation, London, 1890.

path of physio-chemical methods and explanations for the broad and easy road of "baseless and senseless hypotheses,"[1] who can doubt that the progress of physiology was thereby delayed? Whatever may seem to be the difficulties ahead, however inadequate our methods may appear, the history of physiology, like that of the other experimental sciences, teaches us in the clearest possible way that if we follow steadfastly the advice of our greatest teachers and continue to experiment, to try, new methods will be developed continually which will prove adequate to the fruitful investigation of the seemingly impossible problems that confront us. We have many examples in our own subject of the unwisdom of crying *ignorabimus.* Take the instance of the velocity of the nerve impulse. The greatest living master of physiology, impressed by the idea that the action of the nerve must depend upon the movement of an imponderable material propagated with a velocity comparable to that of light, had declared that it was hopeless to think of arriving at an experimental determination of this velocity within the short distance offered by the animal body. Yet a few years afterward Du Bois Reymond discovered the electrical phenomena of the stimulated nerve, and reasoning from this fact, Helmholtz was led to his beautiful and simple experiments, by means of which the velocity of the nerve impulse was accurately measured. Müller's surrender of the problem was due to a false assumption, and without doubt we or our descendants will find that many of the questions that seem to us beyond the limit of experimental study will be made accessible to investigation by the discovery of new facts and methods. To judge from the past, the greatest danger and mistake lies always in that hopeless attitude of mind which assumes that what is impossible now to our methods and to our limited vision will remain so forever.

[1] Reil, *Archiv für die Physiologie,* vol. I, p. 4, 1796.

I cannot myself see any reason why the physiologist should be despondent of the future, nor why he should depart in any way from the rule laid down by Harvey, "to search out and study the secrets of nature by way of experiment."[1] Those who criticise existing tendencies and methods, and speak vaguely of a better way, have nothing definite to offer, except a return to the barren and disastrous method of speculation by way of the "inner sense."[2]

There are certain large problems in biology which, by definition at least, belong to physiology, but which as a matter of fact do not at present form a subject of investigation by physiologists. Such, for instance, are the great questions of development and heredity, and the varied and important reactions between the organism and its environment included under the term ecology, or bionomics. The course of development in biology has been such that in recent years these questions have fallen mainly into the hands of the morphologists. But the methods employed by the morphologists in their investigations tend to become more and more experimental, and we may infer that the workers who devote themselves to these problems will be compelled to have recourse more and more to the technical methods of physiology. It is therefore a fair question as to whether or not it is desirable that the specialist in physiology should give his attention to work of this character. Burdon-Sanderson, in an address before the British Association for the Advancement of Science, 1893,[3] took the ground that the field of physiology proper, as determined by the course of development, lies altogether in the province of what he calls the internal relations of the organism, that is, "the action of the parts or organs in their relations to each other." This definition is at least an approximately accurate statement of

[1] Quoted from Pye-Smith, Harveian Oration, *Nature*, vol. XIX, 1893.
[2] Bunge, *loc. cit.*
[3] *Nature*, vol. XIX, 1893.

the scope of physiology as it has existed during the past two or three generations. I say approximately accurate, because as a matter of fact some recognized physiological work has concerned itself with the reactions between the organism and its environment, such work, for instance, as the effect of external temperature upon heat production, or the effects of altitude upon the elements of the blood. Still the reaction to the environment has been studied by the physiologist only in so far as the adaptation can be detected at once or within a relatively short period of time. Those reactions that are detectible only or mainly in the progeny have been left very properly to those sciences whose dominant method is that of observation and comparison. In this regard the history of the physiology offers an analogy to that of physics. Most of the problems of astronomy and geology are in a wide sense physical problems, but in the division of labor made necessary by the extent of the field to be cultivated, the specialist in physics has limited himself to the study of the properties of inanimate matter so far as they can be approached by the methods of laboratory experiment. The wider relations of this matter to the cosmical processes throughout the visible universe, and its transformations during long periods of time, have formed the subject-matter for independent although related sciences. The astronomer or geologist makes much use of physical knowledge and physical methods, but his subject is large enough to form an independent department of science. A similar division of labor has been followed in the sciences that deal with animate nature, and the part that has fallen to the physiologist is mainly the experimental laboratory study of the properties of living matter. It seems proper, and indeed necessary, that the broader ecological problems should form an independent science which will need specialists of its own. Work of this kind cannot be regarded as

lying within the province of the specialist in physiology, although without doubt the development of the physiological sides of the subject will be made largely through methods and technique borrowed or adapted from physiology, and on the other hand the results obtained from ecological work will doubtless exert a reflex influence upon the methods and especially the theories of physiology.

The matter stands otherwise, however, in regard to the deeply interesting and important facts of embryological development. The laws of growth and senescence, the secrets of fertilization and heredity, must be studied in the long run by the physiologist; they are intrinsically physiological problems and must yield at last to the experimental methods of the laboratory. These questions have been studied heretofore chiefly by anatomical methods; but this is the natural order of development. The anatomical side is the simpler; it precedes and serves as a basis for physiological investigation, as the renaissance of anatomy in the sixteenth century formed the logical precursor of a similar awakening in physiology in the seventeenth century. The anatomist has been forced, so to speak, to take up first the problems of development, but of necessity the need for experimental work has soon made itself felt. The results that have been obtained by the use of the simple but ingenious experiments so far employed have been most suggestive, and indicate clearly that a promising future awaits the further extension of this method. If for a time longer such work shall be done mainly by those whose training has been received in the observational sciences, it seems inevitable that the specialist in physiology must also enter the field. Chemical and physical methods are clearly adapted to the study of these problems, for in the end we expect to find the scientific explanation of growth and development in the physical and chemical properties of living matter. The subject is as

truly a part of physiology as the processes of secretion and nutrition. In the current literature upon the subject there is at present a freedom in the formation of hypotheses and a reliance upon the virtues of the syllogism which tend to bring it into sympathetic relations with philosophy rather than with physiology. But as the store of observed and demonstrable data is increased, the boundary-line between the probable and the improbable will be more sharply drawn, and more objective methods and less ambiguous theories will mark the development of the subject along experimental lines.

In the strictly physiological literature of the past century, a characteristic feature has been the absence of philosophical speculation. Although the physiologists have been concerned most directly with the problems of life, they, of all the biological family, have been least productive in the philosophical discussions that have prevailed during this period. Those who were most conspicuous in laying the foundation of our exact knowledge followed upon an age of free speculation, and therefore, as it were by protest against this tendency, devoted themselves to an empirical study of the subject, following the admonition of Harvey mentioned above; of Hunter, whose advice was, "Don't think, try;" and of Magendie, whose guiding principle of work was similarly expressed.

At the present time there are indications that the workers in physiology are dissatisfied with this cautious attitude. There seems to be a reaction against the purely empirical procedure, and a demand for the discussion of the underlying philosophical principles. This tendency, in fact, has seemed to affect all of the experimental sciences. "All sciences," says Ostwald,[1] "are tending to be philosophical;" and he and others see in this fact an indication of the ap-

[1] *Loc. cit.*

proach of an era of synthesis in science, a beginning of the unification of all the widely separated specialties toward a common end. Others will perhaps view this tendency with alarm, and imagine that history is repeating itself; that after a century of objective experimentation the restless mind of man is reverting to the speculative methods of the eighteenth century and attempting after the manner of other days to reach by a shorter path the final goal of an understanding of the mysteries of the universe. Truly, when one examines the results of this recent tendency, he finds in them but little to encourage his hopes of a more rapid advance in knowledge. While many protest against the inadequacy of our present methods, the progress that is actually being made is accomplished, as formerly, by those who adhere to the tried method of experimenting continually in every direction. So far as I can see, it is still the duty of the physiologist to insist upon the necessity and value of empirical work. What we need is not so much philosophical theories as new experimental methods, and these will be discovered only by those who, trained in the technique of the subject, are continually attempting to modify and improve existing methods. Physiology needs a Pasteur rather than a Descartes. It is possible that the sciences of physics and chemistry, being so much farther advanced than that of physiology, may feel acutely the need of reconstructing their philosophical basis in order that their working hypotheses may better adapt themselves to future experimental work, but in physiology the guiding principles which we have received from these sciences still hold out richest possibilities of results, and we have not within the limits of our own subject reached that degree of development which calls for a fundamental change in methods or theory. While deprecating, therefore, in the strongest possible way any effort to minimize the importance of the experimental work as now

carried on in physiology, it seems to me, nevertheless, quite evident that some value must be given also to the character of the general philosophical idea upon which this work is based. The purely agnostic point of view is suited, perhaps, to individual minds; and where our ignorance is so great the empirical attitude is doubtless the most modest, and theoretically the most justifiable. But human nature is such that an entirely neutral and judicial standpoint fails to arouse in it much enthusiasm or strenuous endeavor. In science we need enthusiasm, for much work is to be done, and scientists as a body, like their fellow mortals, are not content to hold themselves aloof from speculations regarding the final object and significance of their labors. The nature of the underlying philosophical belief has always had an important influence upon the extent and character of scientific work, and we must take this factor into our reckoning in any attempt to estimate the conditions that contribute to the advance or to the retrogression of science.

Toward the middle of the nineteenth century magnificent work in physiology was being done in Germany and in France. The methods that were employed by Flourens, Magendie, and Bernard were as productive and as modern as those used by their contemporaries in Germany, but the influence of the latter school was seemingly more widespread, if we may judge this influence by the effect upon the entire body of investigators in physiology. Recent historians,[1] outside of France, trace the modern revival chiefly to the German school, to the work and the influence of Du Bois Reymond, Ludwig, Helmholtz, Brücke, *et al.* It has seemed to me that one reason for the seeming neglect of the equally important work of the French school lies in the fact that the leaders in the German school were animated by a

[1] Tigerstedt, *Zur Physiologie der naturwissenschaftlichen Forschung*, Helsingfors, 1902; Burdon-Sanderson, *loc. cit.*

philosophical principle whose influence not only guided their own work, as it did, indeed, that of the French physiologists, but which was so emphasized and displayed before the eyes of men that it kindled enthusiasm and attracted recruits from all lands to the army of investigators in physiology. The flag under which they marched bore the motto of mechanism, and its followers were animated by the hope that physico-chemical and anatomical methods applied to the experimental study of the properties of living matter would soon bring these mysteries under the control of science. So rapidly indeed were results accumulated in the beginning the over-sanguine believed the end nearly in sight, and the hope was entertained by not a few that we should soon understand the structure of living matter, and perhaps be able to manufacture it with our own hands. We realize now that this hope was premature. We know much more than our predecessors at the beginning of the nineteenth century; the science has marched onward at a rapid rate; but what seemed to be the end of the forest is only a small clearing, an open space, and in front of us still lies an apparently pathless wilderness. Naturally, therefore, the question has arisen as to whether or not we are following the right route; there has been a more or less general revival of the old discussions regarding mechanism and vitalism. On the basis of the knowledge and experience obtained by a century of work, there is a disposition to orient the subject anew regarding these guiding principles of investigation.

Recent writers have recognized various degrees or kinds of vitalism, the mechanical and psychical, the natural and transcendental, and the neo-vitalist, as distinguished from the vitalist of the eighteenth century. Leaving aside ultimate views as to idealism or materialism which can scarcely be supposed to exert any direct influence on scientific work, it seems to me that the vitalist in physiology now is what he

has always been, one who believes that there is a something peculiar, a *quid proprium,* to use Bernard's expression, inherent in or indissolubly connected with living matter, a something that is different from matter and energy as understood in physics and chemistry, a something, therefore, that does not necessarily manifest itself in accordance with so-called physico-chemical laws. The name that we may give to this something matters but little; we may call it soul, animal spirits, vital principle or force, ether, nervous fluid, inner sense, consciousness or psyche, but *plus c'est changé, plus c'est la même chose.* We may differ as to whether this something is connected with living matter in all its forms or whether its manifestations are limited to the nervous tissues, but if we admit its existence as a causal factor in any of the phenomena of life, then it seems to me that we adopt the standpoint of vitalism, and the nature of our work as well as our theories will be influenced thereby. The standopint of the mechanist is simple. He believes that all the properties of living matter are of a chemico-physical nature, that is, properties that are dependent upon the structure and arrangement of the molecules and the eternal characteristics of their constituent parts. The C, H, O, N, S, P, etc., that enter into its composition carry with them their individual properties, and if nothing else is present in living matter, the phenomena exhibited by it must be a resultant of these properties, as the phenomena exhibited by sodium chloride depend upon the combination of the properties of the constituent sodium and chlorine. From this standpoint we may assume that if there is in living matter any recognizable form of energy not hitherto classified, it is intrinsically present in dead matter also, and we may hope to discover its existence by purely physico-chemical methods of investigation, with the probability, indeed, that it will be recognized first by the chemist or the physicist with his more

exact methods and more favorable conditions for quantitative analysis. If we are unwilling to adopt this standpoint, then it seems to me that, unless we deem it wiser to assume an entirely agnostic attitude, we are logically forced to take one of two positions. With the older physiologists we may boldly assume the existence in living organisms of a finer stuff intermingled with the so-called matter, a substance that is not matter as we understand that term in science, but which, in combination with matter, gives to living things their distinctive characteristics; or we may assume the existence in the universe of a reality other than matter, with the belief that it is influenced by and exerts an influence upon matter only in the living form, in some such way as the earlier physicists postulated an ether that can be affected by matter only when in a certain state of vibration. If I read them correctly, most modern scientific authorities adopt substantially this latter point of view. The so-called psychical phenomena of life are differentiated from the physical, but at the same time it is admitted that the subjective or psychical manifestations are dependent upon physico-chemical changes in the material substratum. Huxley states the matter with his usual candor and clearness: "It seems to me pretty plain that there is a third thing in the universe, to-wit, consciousness, which in the hardness of my head or heart, I cannot see to be matter or force or any conceivable modification of either." It is perhaps a question of terms only as to whether this point of view is properly designated as vitalism. Inasmuch, however, as it assumes a something that can be influenced only by living matter, possibly only by special forms of living matter, and in turn can only act upon living matter, it draws a line between the properties of the animate and the inanimate which represents a real distinction, and those who hold to this point of view or

any modification of it can scarcely escape, for want of a better term, the designation of vitalist, even though it is recognized that the reaction between the subjective and the objective world may be governed by laws that are, strictly speaking, as mechanical as those reactions of matter that have been generalized under the laws of physics and chemistry. In this sense I believe that the majority of physiologists belong to the school of vitalists. The methods that they employ and the nomenclature they use are, however, mechanical, because the science recognizes that its ultimate aim is to understand the mechanics of living matter, and that in this way only, if at all, shall we be able to arrive at a conception of the relations of this matter to a reality of a different order. The older physiologists, and some of recent times, have used the conception of vitalism as a convenient and easy means of accounting for many processes which further investigation has shown to be purely mechanical. Experiences of this kind tend to strengthen our belief that most of the unknowns confronting us at present will be analyzed eventually in terms of the conceptions of physics and chemistry; but there is always present in physiology the tendency to assume that what is not clearly or conceivably reducible to the laws of matter and energy must therefore belong to the "irreducible residuum." The nature of this residuum, the connotation of the term vitalism, varies somewhat with each generation.

Bernard, in his lucid and masterly discussion of the phenomena of life, came to the conclusion that the irreducible residuum, to which the laws of chemistry and physics are not and cannot be applicable, is the power of development of the egg. "Car il est clair que cette propriété évolutive de l'œuf, qui produira un mammifère, un oiseau, ou un poisson, n'est ni de la physique ni de la chimie

....La force évolutive de l'œuf et des cellules est donc le dernier rempart du vitalisme."[1] In our own day the study of the mechanics of development is actively pursued by many investigators, and I fancy that few modern physiologists are inclined to take a truly vitalistic view of the process. However much the facts of development are beyond the possibility of explanation in terms of our present chemico-physical knowledge, it is conceivable that the observed processes may all be due solely to the material structure of the fertilized ovum acting in accordance with physico-chemical laws, and that, therefore, our present methods of investigation may eventually bring these phenomena within the limits of a scientific explanation. The irreducible residuum recognized to-day, and indeed admitted always by many of the physiologists who are reckoned among the mechanists, is the psychical reaction, the phenomenon of consciousness. However much we may come to know of the physico-chemical processes that give rise to this reaction, it has been asserted by most of the scientific authorities of our time that the psychical side itself is beyond the possible application of the methods of physics and chemistry, a conclusion that, as it seems to me, is tantamount to the admission of the existence of a non-material reality. The study of consciousness has therefore been eliminated from the subject of physiology on the ground that the methods of our science are inapplicable. I fully agree, however, with the timely and courageous statement of Minot[2] that "consciousness ought to be regarded as a biological phenomenon, which the biologist ought to investigate in order to increase the number of verifiable data concerning it." If for the present this task is confided to the workers in the independent science of

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[1] Bernard, *Revue des Deux Mondes*, IX, p. 326, 1875.

[2] Minot, *Presidential Address*, American Association for the Advancement of Science, Pittsburgh Meeting, *Science*, XVI, p. 1, 1902.

psychology, the only successful methods that they can employ are those of observation and experiment, and eventually the latter mode of investigation must become the more important, and the subject must be recognized as destined to come within the province of experimental physiology. To Minot the most important work at present is to be accomplished by an extension of the comparative method to the psychological study of all forms of life, but to the physiologist it would seem that a no less promising although technically more difficult field will be found in neuro-pathology, which holds out hopes that definite variations in the psychical reaction may be connected with distinct alterations in the structure and properties of the material substratum. One can scarcely doubt that the combined labors of the psychologist, biologist, physiologist, and pathologist will eventually accumulate many verifiable data concerning consciousness. We are not able at present, it is true, to form any conception of the nature of the relation between the subjective and the objective, but new facts may alter wonderfully our insight into this mystery, and it is the clear duty of physiology to participate in the work of accumulating all possible data bearing upon this relation. The introspective method alone is insufficient, and we have no alternative but to trust hopefully in the less pretentious method of scientific observation and experiment. We may believe that in this way a basis will be obtained upon which philosophy may reason, more surely and more successfully than is possible now, concerning the psychical life and its relations to the mechanical phenomena of the universe.

If I may summarize briefly my point of view regarding the present problems of physiology, what I have wished to emphasize in this. The experimental method, physical, chemical, biological, or anatomical is the life and hope

of the subject. Its future depends solely upon the steadfast recognition of the necessity and possibilities of this means of research. Every investigator who is anxious to add to the stock of physiological knowledge should experiment ceaselessly by those methods which he is most capable of using, while those who are looking forward to the highest work in physiology should fit themselves by a thorough training in physics or chemistry, since the most difficult and the most fundamental problems in the subject require the use of the methods and modes of thought of these sciences. There must be an outlying division of workers who will keep the subject in touch with practical medicine, and other divisions through which communications will be established with psychology and the morphological sciences; but the flower of the army, the imperial guard, will consist of those who have been disciplined in the methods of physics and chemistry, and who are able to apply this training to the study of the properties of living matter.

ADVANCES AND PROBLEMS IN THE STUDY OF GENERATION AND INHERITANCE

BY OSKAR HERTWIG

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FROM the time of Greek science until our own day, no other problem has interested the scientific investigator as much as that of animal development. Still after many centuries, difficulties remain that appear insurmountable to human powers. This is especially true of the secret problem of generation. In earlier centuries, the old anatomists with their incomplete methods of investigation could not win true knowledge, which, however, they sought to replace by hypotheses, which were generally without permanent value, and sprang from the earth like mushrooms. At the end of the seventeenth century more than 300 could be enumerated, and when the famous physiologist Haller brought together the work of several centuries, in his great handbook of physiology, he commenced the chapter on generation with the complaint, which was certainly justified at that time, "Ingratissimum opus, scribere de iis, quae multis a

natura circumiectis tenebris velata, sensuum luci inaccessa hominum agitantur opinionibus."

The century of natural sciences, the nineteenth century, was the first to lay a scientific basis for the study of generation, as well as for that of so many branches of natural science. Since then such great advances have been made, that if Haller should, in our day, begin again to write the chapter on generation, he would certainly term it, in contrast to the year 1746, an "opus gratissimum."

For is it not a pleasant task to follow the way in which the torch of science has constantly more brightly illumined a realm, which for many centuries was looked upon as one of the most hidden; also how, on the successfully trodden way, the new discoveries have, with certainty and regularity, been crystallized around the already determined truth? Therefore, I may surely count upon a general interest when I give a comprehensive sketch of the position and problems of our present development in the realm of generation.

The theme corresponds also to the general programme of the Board of Managers of this Congress. It is their object to show, in the great series of addresses which lie before us, a proof of the inseparable connection of all branches of science. Our theme will show us, step by step, how botanists and zoölogists, students of the Protista, anatomists and physiologists, work hand in hand when they investigate the general basic truths of their various sciences in the realm of generation, as here, every step forward in one of these immediately assists each of the others. The goal of truth, for which we seek from various starting points, is the great science of life, biology, to whose investigation the separate ways lead. In another connection still, we shall see how the development of biology is dependent, in more than one connection, upon the develop-

ment of other sciences, especially of physics and chemistry, and thus forms an integral limb in the regular development of the great tree of knowledge. To give a convincing example of this natural connection, the most important discoveries which biology has made in the last hundred years were made possible, in great part, by the development of physics. Consider the advance in physical optics, and the technic connected therewith, which through Abbé's labors gave us the compound microscope, that wonderful instrument already brought to the highest perfection and destined to overcome, in the rapid course of conquest, the new world of the smaller micro-organisms. Embryological investigation, especially, was seen to take a great spring forward the moment physiologic knowledge showed that animals are built up of smaller individuals, the cells, and thus are nothing more than communities of innumerable, socially connected, elementary organisms. Embryology is indebted to the students of plant anatomy for the impulse toward this new study which is built upon the knowledge of the construction and origin of plants, based upon Schleiden's teaching. For, standing upon Schleiden's shoulders, Schwann has shown the dominion of the cell theory in the animal body.

At this time the study of generation received its first scientific basis. The beginning of individual life, the egg itself, is a cell, as Schwann had already conjectured. The spermatozoa also, which in the time of Johann Müller were frequently looked upon as parasitic organisms in the seminal fluid, comparable to infusoria, were soon explained by Kölliker as elementary parts of the animal, as they too arise from cells. Thus the organism reproduces new individuals of its own sort by loosing from their bonds single cells, as sexual products, which may begin an independent life in a new process of development. While until now

the progress came from the botanical side, animal embryology, on the contrary, now began to have a fruitful influence on the study of generation in plants. The question which next pressed itself upon the embryologist was: Why must the egg, that the young being may develop from it, first experience the effect of the semen? Why must it, except in the rare cases of virgin generation, be fertilized? This matter still remained a problem which actively demanded a solution. Ordinarily the process was explained by saying that the egg, in order to begin development and to divide, needed an external stimulus, and that this stimulus to development was a chemical process arising either from the seminal fluid or from the spermatozoa.

Some investigators who endeavored to observe fertilization in suitable objects, believed that they were able to see under the microscope that some of the numerous spermatozoa which surrounded the ovum forced their way in, dissolved, and mixing with the yolk, acted as the fertilizing agent. For a time the question as to the penetration of the spermatozoa in the egg was the burning question of the day in science. What value was laid upon the observation of a spermatozoön inside the yolk-sac, may readily be seen from the fact that Barry, as well as Nelson, Keber, and Meissner, called together a congress of professors and doctors in order to show them the discovery, and to permit them to see the proof for themselves.

The state of the knowledge of generation up to the year 1875, Wundt has expressed as follows in his text-book of physiology: "The important condition for fertilization is, in all probability, the penetration of the spermatozoa into the egg contents, which may be shown in the various classes of vertebrates. After the spermatozoa have penetrated into the egg they rapidly lose their mobility and dissolve themselves in the yolk. We do not possess a theory, or even a

plausible hypothesis, concerning the nature of the process, by which after their penetration into the yolk they provoke in this the process of development."

With the year 1875, a new stage begins in the study of generation. At that time I was fortunate enough during a long sojourn for study at the Bay of Villafranca to determine more accurately the process of fertilization, in an extraordinarily favorable object, the egg of the ordinary sea-urchin, *Toxopneustes lividus*.[1] As in the sea-urchin the sexes are separate, and as the eggs which almost the whole year through may be found in the mature condition are small and transparent, it is here an easy task to observe the artificial fertilization on the object-glass and under the microscope. The complete transparency of the egg permits, even with extreme magnification, the most minute processes to be observed during life. That which has already been discovered can be controlled and more accurately determined in many details in preserved material.

Thus the important points of the process of fertilization could be explained and later positively determined by me and the numerous investigators who have since then occupied themselves with the *Echinodermata* (Diagram I).

After the mixing of the sexual products, numerous spermatozoa approach the egg-cell by a swinging motion of their tails, but only one penetrates, if the egg is normal and capable of life (Fig. 1, *k* and *m*). The point of penetration is known to be a small conical process, the reception eminence (*Empfängnis Hügel*), which extends from the egg-

[1] My investigations on the first stages of development in the egg of the sea-urchin began Easter, 1875, in Ajaccio, where I studied especially the changes in the division of the egg. At that time, however, I did not succeed in observing the process of fertilization, although my attention was directed toward it. I first succeeded when I went from Corsica to Villafranca, with my brother (who was making a study of *Radiolaria*) and there continued my investigations for some time. When, therefore, Bölsche, in the first volume of his encyclopædia *Men of Our Time*, p. 228, writes: "Oscar Hertwig made in Ajaccio the discovery of the act of fertilization in the sea-urchin which will form for a long time a turning-point in the history of our knowledge of the sexual act of generation, thus of one of the deepest mysteries of all nature," the name of the place Ajaccio should be replaced by Villafranca.

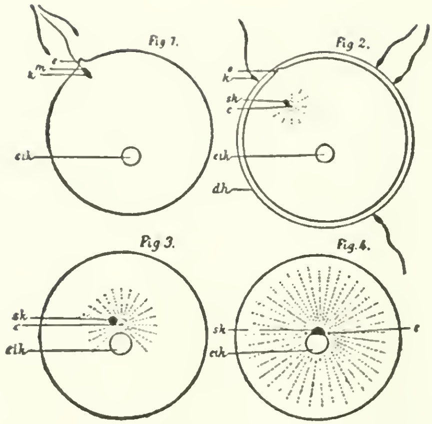

DIAGRAM I. The Fertilization process in the ovum of *Toxopneustes lividus.*

FIG. 1. The mature egg at the moment of fertilization. Of the numerous spermatozoa one has already penetrated the egg at a point which is determined by the "reception eminence." In the spermatozoön the head (k), the middle piece (m), and the terminal filament may be distinguished. The egg-nucleus (eik).

FIG. 2. The egg a few minutes later has excreted the yolk-sac (*Membrana vitellina*). The head and the middle piece have separated from the terminal filament, which has disappeared, and have changed into the male pro-nucleus (sk) and the centrosome (c). The latter is surrounded by protoplasmic rays. The distance between the sperm-nucleus and the egg-nucleus has lessened.

FIG. 3. A few minutes later. The egg and sperm-nuclei have approached one another in the center of the ovum. The originally simple centrosome has divided in two. The protoplasmic rays around the two nuclei have become larger.

FIG. 4. The egg- and sperm-nuclei lie against one another and have become flattened at the place of contact. The centrosomes are arranged on opposite sides of the nuclei. The protoplasmic rays have spread themselves out over the entire yolk.

surface toward the closest spermatozoön. To others, entrance is immediately made impossible by the fact that the egg at once excretes a fine but impenetrable skin, the *membrana vitellina,* largely as a protection against this.[1]

The internal fertilization process immediately follows the external. Of the three parts which, as is well known, may be distinguished in the spermatozoön, the head, the middle piece, and the contractile terminal filament, the last is

[1] The formation of the *Empfängnis Hügel* was first observed by Fol, when, in connection with my experiments, he made a very thorough study of the fertilization process in *Echinodermata* (*Recherches sur la fécondation et le commencement de l'hénogénie,* Genf, 1879).

thrown off and has no more importance in the process. The head, on the contrary, which was formed from the nucleus of the spermatozoön-forming cell, and which contains the chromatin (Fig. 1, *k*, and Fig. 2, *sk*), begins to change into a small round vesicle which I have called the seed or sperm-nucleus, and which by the absorption of juice from the protoplasm begins slowly to increase in size (Figs. 3 and 4, *sk*). The middle piece (Fig. 1, *m*) contains a tiny cell-organ, the much-studied centrosome (Fig. 2, *c*), which in spite of its extreme minuteness plays a striking and important rôle in the division of the nucleus. It moves in front of the sperm-nucleus, and its position in the living cell is easily recognizable, because in its neighborhood, evidently as a result of a stimulus proceeding from it, the protoplasm arranges itself in radial bands in a figure like iron-filings around the pole of a magnet.

Interesting phenomena begin now, in rapid succession, to fix the eye of the observer. The original nucleus of the egg and the newly introduced sperm-nucleus draw mutually together and move with increasing rapidity through the yolk toward one another (Figs. 2, 3, and 4). The sperm-nucleus (*sk*) which is constantly preceded by the radiance with the centrosome (*c*) included therein, changes its place more quickly than the egg-nucleus. Soon the two meet in the middle of the egg (Fig. 3), where they are inclosed by a common radiance which has now extended over the entire yolk. They lie against one another, becoming flattened on the contact surfaces, and then lose their separation from one another with the formation of a common nuclear sac. Egg- and sperm-nucleus are thus united to form a common egg-nucleus in which the chromatin of the male and female sexual cells is contained. At this point the internal process of fertilization may be looked upon as concluded.

Two or more nuclei in the egg-cell were already described several times before 1875 in different objects (mollusks, nematodes) by Warneck (*Ueber die Bildung und Entwickelung des Embryos bei Gastropoden, Bull. de la soc. des. Natur. de Moscou,* vol. XXIII), Bütschli (*Studien über die ersten Entwicklungsvorgänge der Eizelle,* 1876), and Auerbach (*Organologische Studien,* vol. II, 1874), and their coalescence with one another was observed. It, however, occurred to no one to see in this coalescence of egg- and sperm-nuclei the process of fertilization. The nuclei were looked upon as new formations (vacuoles) in the egg whose nucleus had been lost. Bütschli believed that the germinal vesicle was completely thrown off. Auerbach thought it was dissolved by karyolysis. Thus it was taught that when seminal bodies penetrated into the egg-cell, they were destroyed by complete solution.

Born is therefore wrong when he states in an article which appeared in 1898 (*Anatom. Anzeiger,* vol. 14, No. 9), "Auerbach has given the modern study of fertilization its lasting basis. It should never be forgotten that this service belongs to Auerbach alone."

Auerbach was far away from the correct interpretation of the phenomena. He knew only that through the coalescence of two nuclei which arose as vacuoles in the yolk at opposite ends of the egg, material differences, individual mistakes in composition, between the two halves, were adjusted. According to his conception, "The necessity for the whole complex of phenomena is caused by the special peculiarity of the fertilized Nematode eggs, namely, by their elongated shape and by the peculiar condition during the act of fertilization by which the eggs forcing themselves through a narrow canal offer at first only their anterior polar region to the zoösperms."

Otherwise, Auerbach has expressed himself very cor-

rectly as to the relation between his and my investigations in speaking of my work (*Junior Literatur Zeitung,* dritter Jahrgang, 1876, no. 101, p. 107). After a short reference to the contents, he remarks: "These observations confirm, as the author explains, as regards the conjugation of two nuclei of independent origin in the egg, those of the writer, but vary from these in that the author ascribes to the two nuclei not merely, as the present writer, a slight qualitative difference caused by fertilization, and does not look upon them merely as new formations, but rather sees in one the morphological remainder of the egg-nucleus, in the other that of the sperm-cell. It is evident that if, in the further development of the subject, the results won by the author should be confirmed, a new light will be thrown upon the fertilization process, the aim of which would be accordingly a conjugation of the nuclei of a male and female sexual cell." Hensen was among the first to value correctly the importance of the theory of fertilization proposed by me. In his article "The Physiology of Generation," in Hermann's *Handbuch der Physiologie,* vol. VI, part 2, p. 126, he remarks: "This conception of fertilization must be looked upon as a fortunate one. It deepens our knowledge of the process of fertilization because it adds to the previously considered chemical and physical elements the morphological element which is so important in the phenomena of life and inheritance by showing that the essential substance has a definite form. Also the new experiences with regard to the important rôle which the nucleus plays in cell-division, as well as for the study of fertilization, come into play, and at the same time the formation of the polar bodies as a preparatory stage for the conjugation of the nuclei is explained in a far better way than was previously possible."

On the basis of these observations fertilization may be

looked upon as union between two different cells which arise from a male and a female individual. The essential in this process is evidently the union or, to use the expression of Weismann, the amphimixis of the egg and sperm-nuclei. That this is a general law of biologic nature is now doubted by none. For fertilization is the same process in all classes of animals as in the *Echinodermata.* Many of these, such as *Cœlenterata* and *Vermes,* as *Tunicata* and *Mollusca,* as *Crustacea* and *Insecta,* have been investigated by various scientists. The numerous *Vertebrata,* in which the process has been followed, *Mammalia, Reptilia,* and *Amphibia, Cyclostomen* and *Amphioxus,* all show the same process.

The discovery of the fertilization process in animals has immediately brought about similar discoveries in the plant kingdom. The fertilization of *Phœnerogamia,* previously studied without result by many investigators, was now quickly explained by Strasburger. Our knowledge in this and other points was completed by Guignard, Nawashin, and others. We now know that the pollen grain, which is analogous to the spermatozoön of animals, carries into the egg-cell of the ovary a sperm-nucleus which combines with the egg-nucleus. The correspondence is even greater in the *Cryptogamia,* as here externally the vegetable spermatozoid is very similar to the animal spermatozoön, and fertilization proceeds in a similar way. Even among the lowest organisms, *Infusoria, Rhizopoda, Flagellata, Algae,* and *Fungi,* the process of fertilization is seen to be the same.

By this natural law of sexual generation, which is now so surely founded and based upon a complete series of observations, the old discussion which once played so great a rôle in the history of the sciences and engaged for a long time the naturalists and philosophers, the strife between the Ovists and the Animalculists, has been decided.

From the sixteenth to the eighteenth century the dogma of preformation ruled: the doctrine that the embryo of a being was built up of the same organs and parts as the parent, and thus was nothing less than an extraordinarily minute reproduction of it. Most scientists (Swammerdam, Harvey, Spallazani, Bonnet, Haller) looked upon the egg as the performed embryo, as may be seen from the well-known saying, "omne vivum ex ovo." But when Leeuwenhoek, during his microscopic discoveries, found the spermatozoa, the thought occurred to him that the worm-like bodies in the semen which moved independently, and thereby showed a certain resemblance to the lowest organisms, should be more properly considered as the miniature beings. He, therefore, proposed the hypothesis that the spermatozoa penetrated into the egg during fertilization in order that the latter might serve them as a suitable nourishment for their future growth. No less a person than Leibnitz accepted this hypothesis.

Strangely enough, in both hypotheses, which appear to be excluded together with the dogma of preformation, a seed of truth seems to be hidden. For, as is easily seen from our present stand-point, both egg and sperm take an equal part in the formation of the new being. Both are cells, one of which represents the properties of the female, the other the properties of the male progenitors. Both unite to produce a mixed product, which has inherited the peculiarities of both parents.

Here we see again how the development of scientific views in the realm of embryology is dependent upon the contemporary development of all science. We can appreciate the fact that the old scientists could not understand the process of generation, because at that time the lack of microscopic assistance hid from them the conception of the elementary construction of the organisms.

The thought of the union of two organisms into a new unit could not occur to the adherents of the preformation theory, for if embryos are already miniature beings composed of many organs, how could it be possible that they should unite in pairs to form a single individual, and at the same time their organs and tissues flow together into one?

For us who know that the germs are merely cells separated from their parents, thus similar to simple elementary organisms, the conception of an amphimixis has no such difficulty, and for us it is now a determined fact. We can follow under the microscope the union of a male and a female cell and even the union of their component parts, especially their nuclei and the substances contained therein. With the knowledge of amphimixis the phenomenon that children may resemble both their parents, a fact for which scientists until the nineteenth century could give no logical explanation, is brought within our understanding. They resemble both, because they are formed from a union of the substance of the father and mother; in other words, from a paternal and a maternal element.

At this point the problem of generation and fertilization passes over into the most difficult of all problems, the problem of inheritance. However, before we approach this more closely, it will be well to make ourselves familiar with the series of phenomena which stand in the closest relation to the problems of generation and inheritance and also belong to the most important discoveries of modern biology. Here also the discoveries for which we must thank, in the first place, zoölogists and embryologists, have reacted favorably upon the investigations of botanists.

The older zoölogists, Fritz Müller, Loven, and others, had already noticed that from the egg-cells of the most distant classes of animals two minute spheres of protoplasm

were thrown off, a short time before or during fertilization (Diagram III, Figs. 3, 4, 5, *pz*[1], *pz*[2]*p*). These were called the polar bodies, because at the place of their extrusion from the ovum the first plane of segmentation began. Their importance remained an enigma. Many scientists believed that they constituted an excretion by the extrusion of which the egg purified itself of useless substances, before the beginning of its further development. Then Bütschli observed that the nucleus of the unfertilized egg is concerned in the formation of the polar bodies, that it projects from the surface of the yolk in the form of a nuclear spindle, which, as he believed, is then extruded in the form of the polar bodies. This was a great advance, but combined with an error with regard to the entire meaning of the process which soon after was rightly determined by Giard and myself. For more accurate investigation showed us that the polar bodies were not formed by extrusion, but by two true divisions which followed immediately upon one another, and that in the second division half of the spindle and of the chromosomes remained behind in the egg, and here became the nucleus of the mature egg. The process only differed from an ordinary cell-division in that the parts were so unequal in size. The polar bodies should, therefore, better be denoted polar cells.

For what reason and to what end, we may ask, are these two insignificant polar cells formed with such great regularity in the entire animal kingdom? On this also light was soon thrown by the accurate study of an extremely favorable object for investigation, the egg of the horse roundworm, *Ascaris megalocephala,* which has been as productive of results in the study of the process of fertilization as the egg of the *Echinodermata.* Its invaluable advantage consists in the fact that it gives us a deeper insight into the relation of that substance which plays the most im-

portant rôle in the division of the nucleus, namely the chromatin.

Of the chromatin we know by investigations which are among the most brilliant of the histological advances of

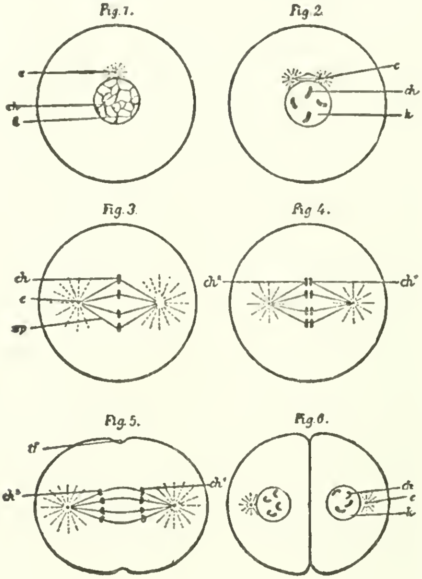

Diagram II. Six stages of cell-division and nuclear division (*Karyokinesis*).

Fig. 1. The first stage. Cell in the resting spherical form, showing a nucleus and one centrosome (*c*). The nucleus shows a network of linine with threads and granules of chromatin (*ch*).

Fig. 2. Second stage. During the preparation for division (pro phase) the chromatin has drawn together into a thread which has immediately broken up into four pieces (chromosomes). The centrosome (*c*) of Fig. 1 has divided, and between the two parts a spindle has arisen.

Fig. 3. Third stage. The spherical nucleus has dissolved. The two centrosomes of Fig. 2 are more widely separated and the spindle between them has become much larger. The four chromosomes (*ch* of Fig. 2) have arranged themselves symmetrically in the middle of the spindle to form the mother star.

Fig. 4. Fourth stage. The four chromosomes of the spindle have split longitudinally each into two daughter chromosomes (*ch* 1 and *ch* 2).

Fig. 5. Fifth stage. The daughter chromosomes which arose by longitudinal splitting have separated further and further from one another toward the opposite ends of the lengthening spindle (formation of two daughter stars). The cell begins the segment in the middle.

Fig. 6. Sixth stage. The segmentation has become complete, and the mother cell is thereby divided in half. In each daughter cell a spherical daughter nucleus, which contains the chromatic substance of four daughter chromosomes (*ch*), has arisen from half of the spindle. By each daughter nucleus (*k*) lies a centrosome (*c*).

the last decennium (see Diagram II, showing nuclear and cell division) that the chromatin at the beginning of the nuclear division is changed into a long convoluted chromatin thread, and that this in the second phase (Fig. 2) breaks up by cross-segmentation into a very definite number of segments or chromosomes (*ch*) which arrange themselves in the middle of the nuclear spindle (Fig. 3, *sp*) to a symmetrical figure, the mother star. Each chromosome then begins to split longitudinally into two identical parts, the two daughter chromosomes (Figs. 3, 4, 5 *ch*). We are justified in seeing in this the true task of the complicated nuclear division, as the two halves now move away from one another toward the opposite ends of the nuclear spindle (Fig. 5, ch^1 *and* ch^2) and form the two daughter stars, which after the division of the cell in two parts form in each the basis of a daughter nucleus. These promptly return to the spherical form.

Extended comparative observations in the most widely separated classes of animals have demonstrated a definite numerical law in the chromosomes. It states: In all cells of an animal or plant species the same number of chromosomes always arise during a division of the nucleus. In one species four, in another twelve or sixteen or twenty-four, etc. The number of chromosomes is four only in one variety of Ascaris. For this reason, and because the few chromosomes are at the same time of very considerable size, the eggs of the horse roundworm are of great advantage for studies in the question which now concerns us.

These remarks with regard to the phenomena of nuclear division must first be made, in order to understand the progress which has been brought about by the study of *Ascaris* eggs in the remarkable investigations of van Beneden, which immediately followed the excellent work of Boveri.

Two fundametnal facts were discovered concerning the behavior of the chromatin in the *Ascaris* egg (Diagram III). One of these facts concerns the process of fertiliza-

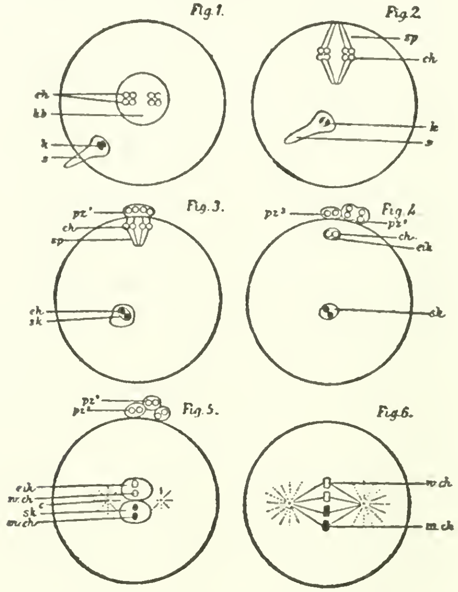

DIAGRAM III. The process of fertilization, the formation of polar cells and the first division of an egg of *Ascaris megalocephala bivalens.*

FIG. 1. The egg at the moment of fertilization. It shows still a spherical nucleus (*kb*) in which the chromatic substance is arranged in two groups of four (tetrads, *ch*). The spermatozoön, shaped like a tailed sphere, has passed half-way into the egg. Its nucleus (*k*) is composed of two chromosomes.

FIG. 2. From the spherical nucleus a spindle with two tetrads has arisen (*ch*). The spermatozoön (*s*) has pressed into the middle of the egg.

FIG. 3. At the animal pole of the egg, where the spindle lay in Fig. 2, the first polar cell (*pzl*) has been formed by budding. It receives from each tetrad of the spinule two chromosomes connected in pairs (a dyad), while the other two chromosome pairs (*ch*) remain behind in the egg with the half spindle (*sp*). The spermatozoön (*sk*) begins to dissolve, except the nucleus, which begins to become spherical.

FIG. 4. In the same way as the first the second polar cell is formed by budding (pz^2). From each of the pairs of chromosomes (Fig. 3, *ch*) of the previous stage, a chromosome comes to live in the second polar cell, while the other remains behind in the egg and forms the egg-nucleus (*cik*), which then contains two chromosomes, as does the spermatazoön (*sk*).

FIG. 5. Egg- and sperm-nucleus approach each other until they touch, but do not unite. In order to distinguish their chromosomes those of the egg-nucleus are drawn as a white circle (*wch*), those of the sperm-nucleus as a black circle (*mch*), as was done in the previous Figs. 1 to 4.

FIG. 6. Egg- and sperm-nuclei have together formed a spindle of whose four chromosomes half (*wch*) arise from the egg-nucleus, the other half (*mch*) from the sperm-nucleus. The polar cells, as in Figs. 7 and 8, have been omitted.

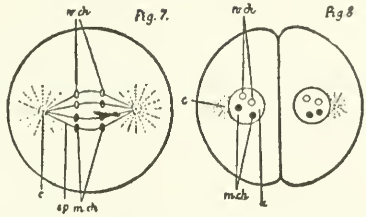

FIG. 7. The female and male chromosomes of Fig. 6 have divided longitudinally and separated from each other in two groups of daughter chromosomes: (*sp*) spindle; (*c*) centrosome.

FIG. 8. The two halves of the egg contain daughter nuclei, half of whose chromosomes arise from the egg-nucleus, half from the sperm-nucleus.

tion. Egg- and sperm-nuclei (Fig. 5, *eik* and *sk*) remain, in the egg of *Ascaris,* separated from one another for several days, and prepare themselves separately for the formation of the first karyokinetic spindle. From the chromatin network, chromosomes arise in the way described above, two in the egg-nucleus (Fig. 5, *wch*), two in the sperm-nucleus (*mch*). We can thus easily follow their fortune in the further stages of division, and determine that of the four chromosomes of the nuclear spindle, two arise from the egg-nucleus, two from the sperm-nucleus. When the chromosomes split longitudinally, in the stage of the mother star, we see their products, the daughter chromosomes, separate from each other, in the way described above (Fig. 7, *wch* and *mch*), to form the daughter stars, and finally enter into the formation of the daughter nuclei of the two new cells. In this case incontrovertible proof has been brought that in the first division of the fertilized egg an equal amount of chromatin from the egg-nucleus and the sperm-nucleus is brought to each of the daughter nuclei.

This process apparently repeats itself in every later division, so that finally the nucleus of every tissue cell is composed of equal amounts of chromatin of maternal and paternal origin, which has been constantly increasing by

growth. Of course the equal division cannot be determined later by direct observation, as is the case in the first division, but after what we know of the nature of nuclear division this view may be considered in the highest degree probable.

Still more important is the second fact determined on the *Ascaris* egg. The chromosomes of the egg- and sperm-nuclei are an exception to the above-mentioned numerical law. Whereas in *Ascaris megalocephala bivalens* four chromosomes always arise from the resting nucleus, only half as many, that is, two, occur in the egg- and in the sperm-nuclei (Figs. 4, 5, *eik* and *sk*). How is this exception from the numerical law to be explained? How is it brought about? A very accurate study of the method of origin of the polar cells, as is possible in *Ascaris,* gives a satisfactory explanation.

Some time before the origin of the polar cells remarkable changes occur in the contents of the nucleus which justify the great consideration which they have received, and which have been the object of extended investigation. In this variety of *Ascaris* four long threads arise from the chromatin network and split longitudinally into double threads before the height of karyokinesis, the usual time of splitting. These threads immediately place themselves across each other, and thus produce, while gradually becoming shorter, a tetrad of chromosomes, a stage which has been shown in the development of many species of animals. When now the nucleus dissolves and the first polar spindle is formed from its contents, the eight chromosomes arrange themselves in the middle, in two tetrad groups. Later each tetrad group, of the first polar spindle, separates into two groups of chromosomes, connected in pairs (Fig. 3), or in other words, each tetrad divides in two dyads,

of which one passes into the first polar cell (*psl*), the other passes into the egg.

And now there occurs a second striking variation from the usual process of nuclear and cell-division. While otherwise, after division, the nuclear substance always passes for a time into the spherical resting state, here it immediately prepares itself for a second division, which leads to the cutting-off of a second polar cell. The half of the first polar spindle remaining in the egg (Fig. 3, *sp*) immediately enlarges itself into a complete spindle, in whose middle the two dyads lie. These immediately separate into their individual elements, of which two are taken up into the second polar cell (Fig. 4, pz^2), and two remain in the egg, and here form the basis of the egg-nucleus. Thus of the entire chromatin mass of the egg-nucleus which was divided into eight chromosomes, the mature egg only contains the fourth part, that is, from each of the two tetrads only one single chromosome (Fig. 4, *eik*, *ch*). Instead of once, as in usual cell-division, the chromatin has been divided twice by two polar divisions; in other words, it has been quartered. Therefore, the egg-nucleus only contains half as much chromatin as the nucleus of an ordinary tissue-cell or an embryonal cell. Immediately after each division, it is, to a certain extent, only half a nucleus, and as such is an exception to the numerical law of chromosomes. Weismann has called the whole process, by which is effected the reduction of the nuclear mass and the number of chromosomes to half, a "reduction division."

As the sperm-nucleus in *Ascaris* only possesses half the number of chromosomes of a normal nucleus, the conclusion may be drawn, that in it also a reduction must have occurred, as occurs in the egg by the formation of the polar cells. By such consideration, I was led to seek for a cor-

responding process in the formation of sperm, which premise showed itself as correct.[1]

As an accurate comparison of the egg- and sperm-formation in *Ascaris* shows, there exists in the two a complete parallel, which may be followed into the smallest detail. The unripe egg with a spherical nucleus, the egg mother cell or ovocyte (Diagram III, Fig. 1), corresponds to the sperm mother cell or spermatocyte (Diagram IV, Fig. 1), as each undergoes a reduction by the formation of polar cells. Also the chromatin arranges itself in the nucleus in this extremely characteristic way which is observed nowhere except in sexual cells in two groups of four each (Diagram IV, Fig. 1 *ch*). Then the sperm mother cell is split up by two divisions, which follow upon one another without a resting stage being interposed, first into two daughter cells (Fig. IV), and immediately by a second division which causes the actual reduction into four granddaughter cells of equal size. By these processes, each of the two tetrad groups (Fig. 2, *ch*, and Fig. 3) divide into two pairs of chromosomes, which are shared by the two daughter cells (Fig. 4). Then each pair of chromosomes (Fig. 5, *ch*) falls again into its individual elements, which are taken up by the granddaughter cells (Fig. 7). These, therefore, contain, as does the mature egg and the polar cells, only a single chromosome from each tetrad group, altogether only two (Figs. 7, 8). Their nuclei are, therefore, reduced to half-nuclei.

Many will have asked, what aim this noteworthy reduction of the chromatin, which constitutes the important

[1] Even before my investigation Platner determined by a study of the process of sperm-formation in *Lepidoptera* and *Pulmonata* a reduction process in the sperm-nuclei, although in a less striking and less comparative way. He drew the conclusion "the spermatocytes correspond to the ova. In both cases a reduction of the chromatic substance to a quarter of its original quantity occurs, while a second division follows immediately on the first without a period of rest between." (Platner, *On the Meaning of the Polar Bodies, Biologisches Centralblatt*, vol. VIII, p. 193, 1889, and *Contributions to the Knowledge of the Cells and their Divisions, Arch. für mikrosk, Anat.*, vol. XXXIII, 1889).

process of egg- and sperm-ripening, may have. The explanation is easily seen if we consider, in connection with the chromatin reduction, the succeeding fertilization, and consider that by this a second nucleus is brought into the egg, which combines with the egg-nucleus and thus doubles its chromatin mass. Thus from two half-nuclei a complete nucleus is again formed, from which then arise all the nuclear generations of the new being. Thus ripening and fertilization of the egg stand to one another in a supplemental relation. That fertilization is needed to replace the chromatin reduction may be proved by a consideration.

As the numerical law of the chromosomes has taught us, chromatin is a substance which shows a tendency to be constant in a given species, not only in relation to its mass, but also in regard to the number of chromosomes in which it splits during karyokinesis. Thus it is a substance which after cell-division increases to the double and is then halved by division, etc. If we now consider that the process of reduction did not occur, then by fertilization two complete nuclei would be united, and the result would be a doubling of the chromatin, in relation to the normal. By every new sexual generation the same process would be repeated, and thus in the course of generations a summation of nuclear substance would be brought about, which in a short time would lead to such a lack of relation between it and the protoplasm, that the contents of a cell would no longer have room for it.

Led by similar considerations we may say: By the reduction which precedes fertilization the summation of the nuclear mass and the number of chromosomes to the double and multiple which is normal for the species under consideration, is hindered in the simplest way possible.

Thus, the phenomenon of reduction is a general biologic law of the greatest value. What has been observed in one

species of animal has gradually been confirmed in numberless other cases, in vertebrates and invertebrates. And time and again that which we have already seen has been repeated. These discoveries of the embryologists placed new problems before the botanist, which he immediately seized and solved. In the sharper position of the question which was now possible, phenomena were gradually observed in the *Phænerogamia* and *Cryptogamia,* which, although not so easily explained as in the animal kingdom, showed that, in the development of the vegetable sexual products, a reduction process by nuclear divisions following close upon one another, also occurred. Even in *Infusoria* and different sorts of lower unicellular organisms, corresponding processes have been observed.

We have reached in the realm of the study of generation a position which has been attained to the same degree in the study of very few of the other complicated phenomena of life. We can unite many facts in a few general laws which possess value for the entire organized world and for which we can use the expression "law" with the same justification and in the same sense as physicists and chemists in their determinations of law-abiding phenomena of lifeless nature. In a few decennaries discoveries have been made, which, supplementing each other, have been connected with each other, and have deepened in an unsuspected way our knowledge of generation.

And as the middle point of these discoveries there stands a well-characterized substance, which is contained in a small amount in the nucleus of every cell, and whose striking changes during cell-division have drawn upon it the attention of biologists, the chromatin. That this wonderful substance must have a great importance in the life of the cell is hardly to be doubted after the foregoing experiences. Let us attempt to penetrate somewhat deeper

into its importance. We are hereby brought back to the important problem of inheritance upon which I already touched in connection with the demonstration of fertilization, but had retained for later mention. If the egg- and sperm-cell conveys to the new being the properties of the father and mother, how does it come about, we may ask, that these share in the process to such an unequal degree, as the egg gives to the new being one hundred or one thousand times more substance than the insignificant spermatozoön? Naegeli, in his book *Concerning the Mechano-Physiologic Theory of Generation,* which is very rich in ideas, has attempted to answer the question by theoretic discussion, by the view that the sexual cells consist of different substances, which possess a different value for the inheritance of parental characteristics. The important sort he designates idioplasm.

Idioplasm is a purely hypothetic conception, for Naegeli himself has not stated what substance in the cell is actually the idioplasm. A real basis must therefore first be won by empiric investigation. This occurred contemporaneously and independently by Strasburger and myself; Weismann, Kölliker, and others soon followed.[1]

Proceeding from the facts of karyokinesis, of fertilization and maturation, I concluded that the substance of the nucleus, and here, especially the chromatin, corresponded to the idioplasm of Naegeli. Three important considerations appeared to me to point in this direction.

First: The chromatin is the only substance known to us which occurs in exactly equal amount in the sperm- and egg-cells. As a proof I will recall briefly the already mentioned brilliant discovery of van Beneden, according to

[1] I have given the different historical and critical opinions, in regard to the theory of fertilization and inheritance, in my article *Comparison of Egg and Sperm Formation in Nematoda, Arch. für mikrosk. Anat.,* vol. XXXVI, pp. 77-127, 1890, and in *Zeit. und Streitfragen der Biologie,* vol. I, p. 16, 1894.

which the egg- and sperm-nuclei of *Ascaris megalocephala bivalens* contain the same number of chromosomes, that is, two, which are of equal size.

Second: The fact that the chromatin is the only substance which passes over in equal quantity from the mother cell to the daughter cell, after it has doubled its volume by nourishment and growth. The complicated process of karyokinesis evidently serves only for this purpose. The arrangement of the chromatin particles in threads, the division of the chromosomes longitudinally, the distribution of their split halves toward the poles of the spindle, and the equal distribution in the daughter cells.

Thus, this substance, in which rests the peculiarity of the organism, is carried down from one cell generation to the next as a valuable inheritance, and thereby is the principle by which every cell of the organism is "idioplasmatically enabled," as Naegeli expresses it, to become the germ of a new individual. Here also numerous phenomena of generation and regeneration find their explanation. For in many plants and lower animals we see that actually almost every small cell complex separated from the rest of the organism is able to reproduce the whole. From the root-cells of a plant, buds may form, to reproduce the aërial part, and from the stem-root, cells may develop, as is seen in slips. This is because, in cells, which during the course of development have adapted themselves for a certain function, the deposits contained in their inherited mass are still slumbering, and may be newly awakened and forced into a definite development.

Thirdly and finally, we may base our opinion upon the chromatin reduction. I might denote this as a proof of the justification of the theory. Without having known of the finer processes which occur during the formation of the polar cells, Naegeli had already shown the necessity of a re-

duction process from purely theoretic considerations. He said: "If, in every propagation by fertilization, the volume of the idioplasm, however constituted, doubles itself, the

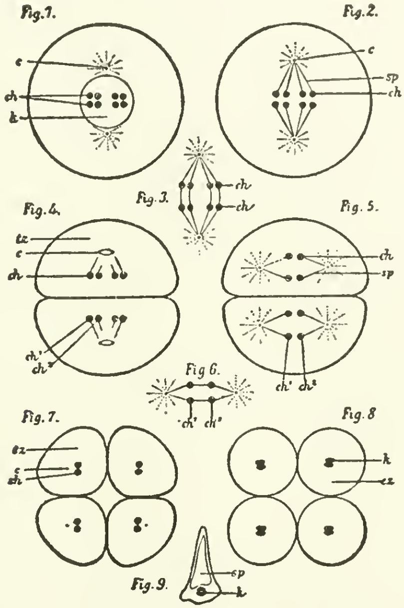

DIAGRAM IV. Spermatogenesis, or development of the seminal bodies from the seminal mother cells (spermatocytes) in *Ascaris megalocephala bivalens.*

FIG. 1. Seminal mother cell with a nucleus (*k*) in which two tetrads (*ch*) have formed. Centrosome (*c*) with rays.

FIG. 2. Seminal mother cell from the nucleus of which a spindle (*sp*) with two tetrads has developed. Centrosome (*c*).

FIG. 3. Spindle in which each tetrad has divided into paired chromosomes (dyads).

FIG. 4. The seminal mother cell is divided into daughter cells (*tz*) each of which incloses a spindle with two pairs of chromosomes (dyads) (*ch*). The centrosome (*c*) has divided into two daughter centrosomes between which a small new spindle is formed.

FIG. 5. The new spindle (*sp*) in each daughter cell has enlarged and included the two pairs of chromosomes (ch^1 and ch^2).

FIG. 6. In each spindle the pairs of chromosomes have separated from one another and approached the poles of the spindle.

FIG. 7. The two seminal daughter cells have divided into four granddaughter cells (*ez*), each of which includes only two chromosomes (one element of the tetrad of Fig. 1) and one centrosome.

FIG. 8. The two chromosomes of the granddaughter cells (*ez*) have flattened against each other eventually to form one small, compact, spherical nucleus (*k*).

FIG. 9. Each granddaughter cell changes into a seminal body (*sp*) conical in shape. Nucleus (*k*).

idioplasm body would be so much increased, after several generations, that it could no longer find room in a spermatozoön. It is thus absolutely necessary that indigenous propagation the union of the parental idioplasm bodies occur without causing, by the united mass, a corresponding increasing growth of this material."

The process suspected by Naegeli was soon after discovered in the development of the polar cells, which, however, were first explained in another way by their discoverer himself, Ed. van Beneden, and were first recognized by Weismann as the process by which a summation of the parental mass as a result of fertilization was prevented. Weismann agrees with Naegeli that reduction was so certainly required by theoretic considerations that the process by which this occurred must be found if it were not contained in already known facts. I, however, doubt as little as does Weismann that the reduction of the idioplasm, which is theoretically demanded, occurs by the formation of polar cells.

When one fact thus agrees with another, which is very rare in this way in biologic processes, we may certainly say, in spite of the objections raised by several investigators, that the idioplasm of Naegeli is found in the chromatin of the cell-nucleus, and that this hypothesis is adapted in a high degree to serve as a starting-point and leading star.

How many questions whose solutions in part we are already beginning to determine, which in part wait upon the future, force themselves upon the investigator!

Does an actual penetration of the two idioplasms occur during the union of the egg- and sperm-nuclei, or do they remain alongside of one another, temporarily or permanently? and in corresponding way, how does the reduction process act? To how many questions, again, the origin

of female and male sex and the generation of bastards gives rise! May we find a morphological basis by the study of the sexual production of bastards for the law of Mendel, which has been confirmed in great part by recent investigations of Tschermak, Correnz, and De Vries on bastards?

And what a perspective the following consideration opens! If the chromatin is the substance by which the peculiarity of each organism is determined, it must be of somewhat different composition in each of the numberless organized species. In the insignificant mass of an egg-nucleus, or a sperm-nucleus in the head of a spermatozoön, only visible under the microscope, the numberless peculiarities by which one species is separated from another are compressed in their elementary forms. Will human intelligence ever succeed in penetrating into this world of the smallest organic differences, which are now invisible to us? Will, in the future, the means of investigation of the biologists, perhaps the discovery of a more powerful microscope and the mastery of the same, increase the circle of vision of our successors as much as was done by the discovery and mastery of the compound microscope?

Or, will the chemist succeed in so increasing his knowledge of the nature of proteid bodies that we may expect valuable conclusions in regard to the nature and difference of idioplasm, that is, the chromatin substance, from this direction? Who will dare to determine where, and how far away, a limit mav be set to the possibility of human knowledge?

Far, far away lies in any case the goal, shimmering before us in the distance. For its attainment the individual branches of natural science, from to-day on, must have united themselves, by extension of their borders, to a great united science of nature, as the leading spirits are now

trying to consummate. For the investigator who will busy himself with this deepest problem of life must unite in one person biologist, chemist, and physicist. and must master the depths of each of these sciences.

In looking so far into the future, with its unlimited possibilities, we may well repeat the words with which our great teacher, Carl Ernst von Baer concluded the preface to his *Embryology of Animals*: "Until then there will still be a prize for many. The palm, however, will be carried off by that fortunate one for whom it is reserved to refer the active power of the animal body to the general laws of life of the world whole. The tree from which his cradle will be fashioned is not yet planted."

WORKS OF REFERENCE ON THE SECTIONS OF BACTERIOLOGY, HUMAN ANATOMY, AND PHYSIOLOGY

(Prepared by the courtesy of Professor Henry B. Ward of the University of Nebraska.)

BACTERIOLOGY

ABBOTT, A. C., Principles of Bacteriology. Philadelphia, 1901.

BESSON, Technique Microbiologique et Sérothéropique. Paris, 1897.

CHESTER, F. D., Manual of Determinative Bacteriology. New York, 1901.

CONN, H. W., Agricultural Bacteriology. Philadelphia, 1901.

DE BARY, A., Vorlesungen über Bakterien. 3d ed. edited by W. Migula. Leipzig, 1900.

DIEUDONNÉ, A., Immunität, Schutzimpfung und Serumtherapie. 2. Aufl. Leipzig, 1900.

DUCLAUX, E., Traité de Microbiologie. Paris, 1898.

EYRE, J. W. H., Elements of Bacteriological Technique. Philadelphia, 1902.

FISCHER, A., The Structure and Functions of Bacteria. Translated by A. Coppen-Jones. Oxford, 1900.

HORROCKS, W. H., An Introduction to the Bacteriological Examination of Water. London, 1901.

JOERGENSEN, A., Die Mikroorganismen der Gährungsindustrie. 4. Aufl. Leipzig, 1900.

KOLLE, W., und WASSERMANN, A. [and others], Handbuch der Pathogenen Mikroorganismen. 4 bde. und Atlas. Jena, 1902.

LAFAR, F., Handbuch der technischen Mykologie. (A new edition is announced.) 2 vols. Jena, 1897, 1903. (Translated in part by Salter. New York, 1898-1903.)

LEHRMANN, K. B., and NEUMANN, R. O. Atlas and Principles of Bacteriology. Translated by G. O. Weaver. 2 vols. Philadelphia. 1901.

MCFARLAND, JOSEPH, Textbook upon the Pathogenic Bacteria. 3d ed. Philadelphia, 1900.

MACÉ, E., Atlas de Microbiologie. Paris, 1897-98.

METCHNIKOFF, E., Immunity in Infective Diseases. Translated by F. G. Binnie. New York, 1905.

Migula, W., System der Bakterien. 2 Bde. Jena, 1897-1900.
Miquel, P., Manual pratique d'analyse bactériologique des eaux. Paris, 1891.
Miquel, P., and Cambier, R., Traité de Bactériologie pure et appliqué. Paris, 1902.
Muir, R., and Ritchie, J., Manual of Bacteriology. Revised from the 3d English edition. New York, 1903.
Nocard, E., et Leclainche, E., Les maladies microbiennes des animaux. Paris, 1892.
Novy, F. G., Laboratory Work in Bacteriology. Ann. Arbor, 1899.
Park, W. H., Pathogenic Micro-organisms, including Bacteria and Protozoa. 2d ed. Philadelphia, 1905.
Procedures recommended for the study of Bacteria. Report of a Committee of the American Public Health Association. Concord, N. H., 1898.
Prescott, S. C., and Winslow, C. E. A., Elements of Water Bacteriology. New York, 1904.
Rideal, S., Water and its Purification. London, 1902.
Smith, E. F., Bacteria in Relation to Plant Diseases. Vol. i. Carnegie Institution, Washington, D. C., 1905.
Standard Methods of Water Analysis. Committee of American Public Health Association. Published by Journal of Infectious Diseases. Chicago.
Sternberg, G. M., Manual of Bacteriology. New York, 1892.
Textbook of Bacteriology. New York, 1901.
Vaughan, V. C., and Novy, F. G., Cellular Toxins. 4th ed. Philadelphia, 1902.
Annales de l'Institut Pasteur. Paris.
Centralblatt für Bakteriologie und Parasitenkunde. Jena.
Journal of Pathology and Bacteriology. Edinburgh.
Journal of Infectious Diseases. Chicago.
Journal of Medical Research. Boston.

EMBRYOLOGY

Baer, C. E. von, Ueber Entwickelungsgeschichte der Thiere. Beobachtung und Reflexion. Königsberg, 1828, 1837.
Balfour, F. M., A Treatise on Comparative Embryology. London, 2d ed., 1885-86.
A Monograph on the Development of Elasmobranch Fishes. London, 1878.
Davenport, Chas. B., Experimental Morphology, 2 vols. New York, 1897-99.
Duval, M., Atlas d'embryologie. Paris, 1888.

GOETTE, A., Die Entwickelungsgeschichte der Unke (Bombinator igneus) als Grundlage einer vergleichenden Morphologie der Wirbeltiere. Mit einen Atlas. Leipzig, 1875.

HATSCHEK, B., The Amphioxus and its Development. Translated by J. Tuckey. London, 1891.

HERTWIG, O., Die Zelle und die Gewebe. Grundzüge der allgemeinen Anatomie und Physiologie. 2 Bde. Jena, 1892-98. (Vol. I, translated by M. and H. J. Campbell, London, 1895.)

Textbook of the Embryology of Man and Mammals. Translated by E. L. Mark. London, 1892.

[and others], Handbuch der vergleichenden und experimentellen Entwickelungslehre der Wirbeltiere. Vollständig in etwa 20 Lieferungen. Jena, 1901-.

HIS, W., Anatomie menschlicher Embryonen. Leipzig, 1880-86.

Unsere Körperform und das physiologische Problem ihrer Entstehung. Leipzig, 1874.

KEIBEL, F. [and others]. Normentafeln zur Entwickelungsgeschichte der Wirbeltiere. Heft I, Schwein; Jena, 1897. Heft II, Huhn; Jena, 1900. Heft III, Ceratodus; Jena, 1901. Heft IV, Eidechse; Jena, 1904.

KOLLMANN, J., Lehrbuch der Entwickelungsgeschichte des Menschen. Jena, 1898.

KORCHELT, E., and HEIDER, K., Textbook of the Embryology of Invertebrates. Translated by various authors. 4 vols. London, 1895-1900.

McMURRICH, J. P., Development of the Human Body. Philadelphia, 1903.

MARSHALL, A. M., Vertebrate Embryology. New York, 1893.

MINOT, C. S., Human Embryology. New York, 1892.

MORGAN, TH. H., The Development of the Frog's Egg. An Introduction to Experimental Embryology. New York, 1897.

PREYER, W., Specielle Physiologie des Embryos. Leipzig, 1885.

ROUX, W., Gesammelte Abhandlungen über die Entwicklungsmechanik der Organismen. 2 Bde. Leipzig, 1895.

SELENKA, C., Studien über Entwickelungsgeschichte der Tiere. Hefte I-VII. Wiesbaden, 1883-1900.

WILSON, E. B., The Cell in Development and Inheritance. 2d ed. New York, 1900.

ZIEGLER, H. E., Lehrbuch der vergleichenden Entwicklungsgeschichte der niederen Wirbeltiere. Jena, 1902.

Archiv für Entwickelungsmechanik der Organismen. Leipzig.

Archiv für mikroskopische Anatomie und Entwickelungsgeschichte. Bonn.

Ergebnisse der Anatomie und Entwickelungsgeschichte. Wiesbaden.

HUMAN ANATOMY

v. Bardeleben, C. [and others], Handbuch der Anatomie des Menschen. 8 Bde. Jena, 1902.

Barker, L. F., The Nervous System and its Constituent Neurones. New York, 1899.

Boehm, A. A., and von Davidoff, M., Text-book of Histology. Translation edited by G. C. Huber. Last edition. Philadelphia.

Braune, W., Topographisch-anatomischer Atlas. Leipzig, 1888.

Cunningham, D. J., Textbook of Human Anatomy. New York, 1902.

Deaver, J. B., Surgical Anatomy. 3 vols. Philadelphia, 1900-1903.

Dejerine, J., Anatomie des centres nerveux. 2 vols. Paris, 1895.

Donaldson, H. H., The Growth of the Brain. New York and London, 1895.

Edinger, L., Anatomy of the Central Nervous System of Man and of Vertebrates in General. Translated by W. S. Hall. Philadelphia, 1899.

Gegenbaur, C., Lehrbuch der Anatomie des Menschen. 7 Aufl. Leipzig, 1898.

v. Gehuchten, A., Anatomie du système nerveux de l'homme. 3d ed. Louvain, 1900.

Gordinier, H. C., The Gross and Minute Anatomy of the Central Nervous System. Philadelphia, 1899.

Gray, H., Anatomy, Descriptive and Surgical. New American Edition. Rev. by J. C. de Costa. Philadelphia, 1905.

Huntington, G., The Anatomy of the Human Peritoneum and Abdominal Cavity, considered from the standpoint of Development and Comparative Anatomy. New York, 1903.

Krause, W., Handbuch der Anatomie des Menschen, mit einen Synonymenregister. Auf Grundlage der neuen Baseler anatomischer Nomenklatur unter Mitwirkung von W. His und W. Waldeyer und unter Verweisung auf den Handatlas von W. Spalteholz bearbeitet. Leipzig, 1898.

Merkel, F., Handbuch der topographischen Anatomie. Braunschweig, 1898.

Morris, H. [and others], Textbook of Human Anatomy. 3d ed. Philadelphia, 1902.

Obersteiner, H., The Anatomy of the Central Nervous Organs in Health and in Disease. Translated by A. Hill. London, 1900.

Oppel, A. [and others], Lehrbuch der vergleichenden mikroskopischen Anatomie der Wirbeltiere. (6 vols. already issued.) Jena, 1896-1905.

Poirier, P., et Charpy, A., Traité d'anatomie humanie. 5 vols. Paris, 1899-1904.

QUAIN, J., Elements of Anatomie. Ed. by E. A. Schäfer and G. D. Thane. 10th ed., 3 vols. London and New York, 1892-96.

Reference Handbook of Medical Sciences. Revised Edition. (Many original articles by prominent writers on special parts of the subject.) New York.

SOBOTTA, J., Atlas der Anatomie des menschlichen Körpers. München, 1904.

SPALTEHOLZ, W., Hand Atlas of Human Anatomy. Translated by L. F. Barker. 3 vols. Leipzig and New York, 1900-04.

SZYMONOWICZ, L., Textbook of Histology. Translation edited by J. B. MacCallum. Philadelphia, 1902.

TESTUT, L., Traité d'anatomie humaine. 2 vols. Paris, 1899-91.

TOLDT, CARL, Anatomischer Atlas für Studirende und Aerzte. Unter Mitwirkung von A. D. Rosa. Wien und Leipzig, 2 Aufl., 1900.

WIEDERSHEIM, Structure of Man as an Index to his Past History. Translated by H. and M. Bernard, London, 1895.

American Journal of Anatomy. Baltimore.

Anatomischer Anzeiger. Jena.

Archiv für Anatomie und Entwickelungsgeschichte. Leipzig.

Journal of Anatomy and Physiology. London.

PHYSIOLOGY

ATWATER, W. O., The Chemistry of Foods and Nutrition. 1887. (Also more recently, several bulletins printed by the U. S. Department of Agriculture, Washington, D. C.)

BERNARD, CLAUDE, Leçons sur les phénomènes de la vie communs aux animaux et aux végétaux. 2 vols. Paris, 1878-79.

BETHE, A., Allgemeine Anatomie und Physiologie des Nervensystems. Leipzig, 1903.

BIEDERMANN, W., Electrophysiology. 2 vols. Translated by F. A. Welby. London, 1896.

BILLINGS, J. S. [and others], Physiological Aspects of the Liquor Problem. New York, 1903.

CHITTENDEN, R. H., Physiological Economy in Nutrition. New York, 1904.

DAVENPORT, C. B., Experimental Morphology. 2 vols. New York, 1897, 1899.

DONALDSON, H. H., Growth of the Brain. New York, 1895.

FOSTER, M., Textbook of Physiology. 5 vols. 6th ed. London, 1893-1900.

HALL, W. S., Textbook of Physiology. 2d ed. Philadelphia, 1905.

HALLIBURTON, W. D., Textbook of Chemical Physiology and Pathology. New York, 1891.

HAMBURGER, H. J., Osmotischer Druck und Ionenlehre. Bd. 1, Wiesbaden, 1902.

HAMMARSTEN, O., Textbook of Physiological Chemistry. From 5th German edition. Translated by J. A. Mandel, New York, 1904.

HELMHOLTZ, H. L. F., On the Sensations of Tone as a Physiological Basis for the Theory of Music. Translated by A. J. Ellis. 2d ed. New York, 1885.

HELMHOLTZ, H. VON, Handbuch der physiologischen Optik. Hamburg, 1866-1896. 2d. ed.

HERMANN, L., Lehrbuch der Physiologie. 11. Aufl. Leipzig, 1896.

HOPPE-SEYLER, F., Handbuch der physiologisch- und pathologisch-chemischen Analyse. 7. Aufl. Berlin, 1903.

HOWELL, W. H., Textbook of Physiology. Philadelphia, 1905.

KREHL, L., Pathologische Physiologie. 2. Aufl. Leipzig, 1898.

LOEB, J., Comparative Physiology of the Brain. New York, 1900. Studies in General Physiology. 2 vols. Chicago, 1904.

MILNE-EDWARDS, H., Leçons sur la physiologie et l'anatomie comparée. 14 vols. Paris, 1857-1880.

OPPENHEIMER, C., Die Fermente und ihre Wirkungen. 2 Aufl. Leipzig, 1903.

PAWLOW, The Work of the Digestive Glands. Translated by W. H. Thompson. London, 1902.

PREYER, W., Specielle Physiologie des Embryos. Leipzig, 1885.

RICHET, CH., Dictionnaire de physiologie. (In publication.) 1894.

SCHAEFER, E. A., Textbook of Physiology. Edinburgh and London. 2 vols. 1898-1900.

STEWART, G. N., Manual of Physiology. Philadelphia. 4th ed., 1901.

TIGERSTEDT, R., Lehrbuch der Physiologie des Kreislaufes. Leipzig, 1893.

Lehrbuch der Physiologie des Menschen. 2. Aufl. 2 Bde. Leipzig, 1902. (An English translation is announced.)

VERWORN, M., General Physiology. Translated by F. S. Lee. New York, 1899.

VIERORDT, Anatomische, physiologische, und physikalische Daten und Tabellen. Jena, 1893.

VON STEIN, S., Die Lehren von den Funktionen der einzelnen Theile des Ohrlabyrinths. Jena, 1894.

ZWAARDEMAKER, H., Die Physiologie des Geruchs. Leipzig, 1895.

American Journal of Physiology. Boston.

Archiv für die gesammte Physiologie des Menschen und der Thiere. Bonn.

Ergebnisse der Physiologie. Wiesbaden.

Journal of Physiology. London.

Zeitschrift für physiologische Chemie. Strassburg.

SPECIAL WORKS OF REFERENCE ON THE SECTION OF BACTERIOLOGY

(*Prepared by the courtesy of Professor Edwin O. Jordan.*)

ASCHOFF, L., Ehrlich's Seitenkettentheorie, Jena, 1902.

BIGGS, H. M., The Administrative Control of Tuberculosis, Medical News, vol. 84, p. 337, 1904.

CELLI, A., La Malaria in Italia durante il 1902, Annali d' Igiene sperimentali, vol. 13, p. 307, 1903.

Die Bekämpfung des Malaria (Koch, R., und Ollmig), die Malariabekämpfung in Brioni (Frosch, P.), in Puntacroce (Bludau), in der Maremma Toscana (Gosio, B.), etc., Zeit. f. Hyg., vol. 43, part I. 1903.

DUCLAUX, E., Traité de Microbiologie. Paris, 1898.

EHRLICH, P., Gesammelte Arbeiten zur Immunitätsforschung, Berlin, 1904.

FICKER, M., Typhus und Fliegen, Archiv f. Hyg., vol. 46, p. 274, 1903.

FLUEGGE, C., Die Mikroorganismen. Leipzig, 1896.

HAMILTON, A., The Fly as a Carrier of Typhoid. Journal of the American Medical Association, p. 577, 1903.

HUTCHINSON, R. H. and WHEELER, A. W., An Epidemic of Typhoid Fever due to Impure Ice, American Journal of Medical Science, vol. 126, p. 680, 1903.

JORDAN, E. O., The Purification of Water Supplies by Slow Sand Filtration, Journal of the American Medical Association, p. 850. 1903.

KOLLE, W., und WASSERMANN, A., Handbuch der Pathogenen Mikroorganismen, Jena, 1903.

LAFAR, F., Handbuch der Technischen Mykologie, Jena, 1904.

La Société pour les études de la Malarie (1898-1903), Archives italiennes de Biologie, vol. 39, p. 427, 1903.

LAVERAN, A., and MISNIL, F., Trypanosomes et Trypanosomiases, Paris, 1904.

LOEFFLER, F., Die Geschichtliche Entwickelung der Lehre von den Bacterien, Leipzig, 1887.

MALLORY, F. B., and WRIGHT, J. H., Pathological Technique, Philadelphia, 1901.

METCHNIKOFF, E., L'Immunité dans les Maladies Infectieuses, Paris, 1901.

MIGULA, W., System der Bacterien, Jena, 1897.

Newman, G., Channels of Typhoid Infection in London, Practitioner, vol. 72, p. 55, 1904.

Nocard, Ed., and Leclainche, E., Les Maladies Microbiennes des Animaux, Paris, 1905.

bridge, 1904.

Nuttall, G. H. F., Blood Immunity and Blood Relationship, Cam-

Ross, R., Report on Malaria at Ismaila and Suez, Liverpool School of Tropical Medicine, mem. 9, 1903.

Schueder, Zur Aetiologie des Typhus. Zeit. f. Hyg., vol. 38, p. 343. 1901.

Sedgwick, W. T., Principles of Sanitary Science and the Public Health, New York, 1902.

Smith, E. F., Bacteria in relation to Plant Diseases, Washington, 1905.

Vital Statistics of the City of Chicago for the years 1899-1903, inclusive. Chicago, 1904.

Weyl, T., Handbuch der Hygiene, Jena, 1893.

SPECIAL WORKS OF REFERENCE ON THE SECTION OF EMBRYOLOGY

(Prepared by the courtesy of Professor Oscar Hertwig.)

BENEDEN, ED. VON, Recherches sur la maturation de l'oeuf, la fécondation et la division cellulaire. Archives de Biologie, vol. IV, Paris, 1883.

BENEDEN and NEGT, Nouvelles recherches sur la fécondation de l'oeuf chez l'ascaride még. Bulletin, Academie Royale de Bélgique, An. III, 1887.

BOVERI, Zellenstudien; Jenäische Zeitschrift für Naturwiss. 1887, 1888, 1890. (Cell Studies.)

Fecundation, Ergebnisse der Anat. und Entwicklungsgeschichte, 1892.

Ergebnisse über die Konstitution der Chromatischen Substantz des Zellkerns. Jena, 1904.

BUETSCHLI, Studien über die ersten Entwicklungsvorgänge der Eizelle, die Zelltheilung und die Conjugation der Infusorien. (Studies on the early development of the ovum, cell division, and conjugation in Infusoria.) (Senckenburg Naturforscher Gesellschaft, vol. x, 1876.)

FOL, Recherches sur la fécondation et la commencement de l'hénogenie. Mém. de la Société de Phys. et d'Histoire Naturelle. Genève, 1879.

GUIGNARD, Nouvelles études sur la fécondation. Annales des Sciences Nat. Botanique, J. XIV, 1891.

HERTWIG, OSCAR, Beiträge zur Kenntniss der Bildung, Befrüchtung und Theilung des Thierischen Eies. Morphol. Jahrbuch. (Contributions to the knowledge of the formation, fecundation, segmentation and division of the animal ovum), vol. I, 1875; vol. III, 1877; vol. IV, 1878.

Das Problem der Befrüchtung und der Isotropie des Eies, eine Theorie der Vererbung. (Jenäische Zeitschrift für Naturwiss. vol. XVIII, 1884.)

Vergleich der Ei- und Samenbildung bei Nematoden, eine Grundlage für zellulare Streitfragen, Archiv. f. Mikroskopische Anatomie, vol. XXXVI, 1890.

HERTWIG, RICHARD, Ueber die Conjugation der Infusionen. Report of the Bavarian Academy of Sciences, vol. XVII, 1889.

Eireife und Befruchtung, chapter II of the Manual of Comparative and Experimental Evolution-Science of Vertebrates. Jena, 1903.

MARX, E. L., Maturation, fecundation and segmentation of Limax. Comp. Bulletin of the Museum of Comp. Zoölogy, Harvard University, vol. VI, 1881.

MAUPÀS, E., Le rajeunissement Karyogamique chez les cilies. Archiv. de Zoologie Expér. et Génér. vol. VII, 1889.

NAEGELE, C. V., Mechanische-Physiologische Theorie der Abstammungslehre, 1884.

RUECKERL, Ueber das Selbständigbleiben väterlichen und mütterlichen Kernsubstanz, Archiv f. Mikroskopische Anatomie, vol. XLV, 1895.

STRASSBURGER, E. v. Neue Untersuchungen über den Befrüchtungsvorgang bei den Phänerogamien. Jena, 1884. (Recent investigations on the process of fertilization in phanerogamia.)

WEISSMANN, A., Uber die Zahl der Richtungskörper und über ihre Bedeutung für das Vererbung, Jena, 1887. (On the number of polar bodies and their significance in heredity.)

Amphimixis, oder der Vermischung der Individuen. Jena, 1891.

WILSON, EDMUND B., Atlas of Fertilization and Karyokinesis of the Ovum. New York, 1895.

The Cell in Development and Inheritance. 2d ed., New York, 1900.

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